THE PLANT DISEASE REPORTER

Issued By

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UNITED STATES DEPARTMENT OF AGRICULTURE

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Paul R. Miller

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CONTENTS

RACIAL POPULATION DYNAMICS IN TILLETIA CARIES AND T. FOETIDA AS INFLUENCED BY WHEAT VARIETAL POPULATIONS IN THE PACIFIC NORTHWEST[1]

E. L. Kendrick and C. S. Holton[2]

Summary

With susceptible wheat varieties such as Hybrid 128, Golden, Baart, Pacific Blue-stem, Federation, Red Russian, Jones Fife, Triplet, and Elgin predominating from 1900 through 1952, the simplest pathogenic races were the ones most frequently identi-fied. However, the resistant varieties Albit, Rex, Hymar, Rio, and Ridit, released during this same period but grown only to a limited extent, did serve to screen out and perpetuate new and more complex pathogenic races. The mounting severity of the smut problem in Elgin wheat in 1950 led to the release of Elmar which tested resistant to half the known races. With the widespread growth of Elmar came a pronounced increase in the prevalence of a group of races previously identified from Rex and Hymar. Thus, smut soon became a critical problem in Elmar, and relief was sought through the re-lease in 1956 of Omar which was resistant to all races known at that time. However, within a year a new race was identified from Omar. Thus, racial dynamics in the bunt species as influenced by necessary changes in varietal populations has been the key fac-tor in the perpetuation of the smut problem in the Pacific Northwest.

INTRODUCTION

To detect the origin and establishment of new races of Tilletia caries (DC.) Tul. and T. foetida (Wallr.) Liro and keep abreast of annual trends in populations of known races, collec-tions of wheat smut (bunt) are made annually throughout the Pacific Northwest wheat-growing areas and identified as to race and source. This information provides a basis for varietal rec-ommendations and also guides the plant pathologists and wheat breeders in their cooperative programs of developing smut-resistant varieties for the region.

As early as 1936 it was suggested (8) that newly introduced wheat varieties acted as a "prov-ing ground" for races of the bunt fungi that might otherwise remain obscure. Since then it has been shown experimentally (6, 7) that host selectivity is an important factor in the estab-lishment of physiologic races of the bunt fungi. This paper reviews the record of bunt race and wheat variety populations in the Pacific Northwest for the past 60 years, a record which substantiates the principles established earlier (6, 7) and graphically illustrates the dynamics of racial populations of the bunt fungi in relation to varietal populations.

RESULTS

In this paper, varietal and racial populations in the Pacific Northwest are discussed under five significant periods: 1900-1930; 1931-1947; 1948-1952; 1953-1957; 1958-1960. The major varieties referred to are those constituting over 10% of the total wheat area of the Pacific Northwest; the minor varieties are those making up less than 10% (13).

Bunt races and methods used in their identification have previously been described (9, 11, 12). A simple pathogenic race is one that is pathogenic in varieties whose resistance is conditioned by but a single factor or resistance type, which in turn conditions resistance to but a few of the 28 known races. In contrast, a complex pathogenic race is one that is pathogenic in varieties whose resistance is conditioned by two or more factors or resistance types or by a single fac-tor which conditions resistance to the majority of the 28 races.

1900 - 1930

Wheat Varietal Populations: A relatively large number of varieties constituted the major wheat acreage of the Pacific Northwest from 1900 through 1930. Turkey, one of the group of

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Crimean hard red winter wheats (1), was the most widely grown of the major varieties of this period and it was susceptible to all bunt races except race T-1 to which it exhibited a high degree of resistance (4).

The white winter varieties Hybrid 128 and Goldcoin, which are susceptible to all races, were next in total acreage among the major varieties, followed by such spring wheats as Baart, Pacific Bluestem, and Federation which carried either no smut resistance or at most the Martin gene M_2, (2, 14) which conditions resistance to only 5 of 28 known races.

Of importance during this period in the minor variety category were Red Russian, Jones Fife, Triplet, Ridit, and Albit. The soft red winter varieties Red Russian, Jones Fife, and Triplet are equally as susceptible to bunt as the white wheats Hybrid 128 and Goldcoin and, together with these latter two varieties, these highly susceptible varieties constituted the major wheat acreage of this period (4, 5).

Two resistant varieties, Ridit and Albit, were introduced in 1923 and 1926 (1) respectively. Ridit, a hard red winter wheat, was the first smut-resistant variety developed and released for production in the Pacific Northwest. It provides resistance to 23 of the 28 races (3). Albit, a white club variety which carries the Martin gene M, is resistant to about half of the known races (2).

Racial Populations: Although a fairly wide range of pathogenicity was represented by the races identified during this period, the simplest pathogenic races, T-1 and L-1, predominated. These two races are pathogenic in varieties carrying no resistance factors or in those possessing only the M_2 factor. Races T-6, T-7, T-8, and L-7 which can infect varieties possessing both Martin factors (M and M_2) for resistance were encountered only occasionally during this period.

The influence of varietal populations on racial populations became apparent soon after the introduction of Ridit. Races T-11 and L-10, both pathogenic in this highly resistant variety, were identified from field collections made from Ridit, portending the smut problem that later developed in it.

1931 - 1947

Varietal Populations: Turkey wheats continued to be the most widely grown varieties during 1931-1947. In the meantime, some highly resistant types were selected from it, and the resistance of these selections was later determined to be conditioned by the T (Turkey) gene (2), which conditions resistance to all but four races. While some of these resistant Turkey types were included under the varietal name Turkey, the greatest portion of Turkey grown during this period was highly susceptible.

Rio, a selection from one of the Crimean wheats (1), was found to be resistant to the same races as the resistant Turkey selections. However, it possesses a different gene, designated the R (Rio) gene (2), which conditions resistance to the same races as the T gene. Rio was released in 1931 but enjoyed limited production.

Of significance during this period was the introduction in 1933 (1) of the resistant variety Rex, a soft white, red chaff wheat that carries both Martin genes for resistance. Goldcoin and the spring wheats which carry little or no smut resistance made up the remainder of the major acreage, while the resistant varieties Ridit, Albit, and Hymar constituted minor acreage during this period. The club varieties Albit and Hymar were important in the heavy soils of the Palouse region. Hymar, which carries the same resistance as Rex, was introduced in 1935 (1).

Racial Populations: Because of the low incidence of bunt during 1931-1947, relatively few field collections were made and identified as to race. Nevertheless, the influence of varietal populations on racial populations was evident in the few collections that were identified. Prominent among the races encountered in this period were four Martin type races, T-5, L-4, T-12, and T-14. In addition, two Ridit races, T-11 and L-9, and the Turkey race L-8 were identified but were not widely prevalent.

1948 - 1952

Varietal Populations: A noticeable reduction in the number of varieties constituting the major varietal group is evident in this period. Also, for the first time, the high yielding white wheats replaced the Turkey wheats in total acreage. These included the varieties Elgin, Golden, and Rex. Although the resistant variety Rex was grown more widely than before, it

failed to equal the acreage of either of the two highly susceptible varieties Elgin and Golden. Production of the resistant club variety Hymar continued to be relatively minor, as was also the production of spring wheats.

Racial Populations: As was the case during the period of 1900-1930, races T-1 and L-1 predominated. The Martin factor races T-5, T-6, T-8, L-4, and L-5 were encountered with regularity, especially among collections of smut from the varieties Rex and Hymar. On the other hand, collections from Golden and Elgin usually represented the weaker races T-1 and L-1. Ridit races T-11 and L-10 and the Turkey race L-8 continued to be of minor importance.

A new, highly pathogenic race identified in this period was T-15, which came out of a collection of smut from Oro, a Turkey type variety.

1953 - 1957

Varietal Populations: This period reflects a major and significant change in varietal acreage in the Pacific Northwest, owing primarily to the simultaneous introduction of two new smut-resistant varieties, Elmar and Brevor (15). Not only did a single variety constitute the major wheat acreage of the Pacific Northwest, but for the first time it was a resistant variety. The variety was the club wheat Elmar (Hymar x Elgin), which, like Hymar and Rex, is resistant to about half the known races. It was released in 1949 (1) to replace the highly susceptible variety Elgin. Its companion variety, the soft, white common-type wheat, Brevor, which was intended to replace such varieties as Rex and Golden, lacked the grower appeal of Elmar. Consequently, Elmar became the most intensively grown single variety in the history of the Pacific Northwest. For the first time the Turkey wheats dropped into the minor variety category.

The intensive production of Elmar was accompanied by a severe smut problem which created a demand for a similar variety with more smut resistance. This led to the development and release in 1955 of Omar, the most resistant variety yet developed for this region. Omar combines the Turkey and Martin types of resistance and this combination provided resistance to all races known at the time Omar was released.

Racial Populations: Along with the shift in varietal populations, a major shift in racial populations characterized this period. Races which are pathogenic in varieties possessing the Martin resistance factors (T-4, T-6, T-7, T-8, T-14, L-4, and L-7) made up 90% of the field collections identified in this period. One of these races alone, T-6, constituted 58% of the total collections, suggesting that it is more aggressive in competition with other similar races.

This aggressiveness was confirmed by a test in which a composite of races T-5, T-6, T-7, and T-8 was used in a pathogenicity test with Elmar, in which all of these races are equally pathogenic under conditions of artificial inoculation. This composite inoculum produced a high percentage of smut in Elmar, from which 30 smutted heads were collected at random. Twenty-nine of these proved to be infected by T-6, thus confirming the greater aggressiveness of this race in natural field competition.

Other races identified in minor proportions were T-1, T-2, L-1, and the Ridit races T-11 and L-10. Also, races T-16, T-17, and L-8, all pathogenic in varieties whose resistance is conditioned by the Turkey and Rio genes, were identified in occasional field collections.

The most significant development concerning racial populations during this period was the discovery in 1957 of a new race, T-18, that was collected and identified (10) from the highly resistant variety Omar. This is the only race known that is pathogenic in varieties carrying the combined Turkey and Martin factors for resistance.

1958 - 1960

Varietal Populations: For the third time within a decade, the leading variety of the Pacific Northwest changed. As seed became available, the smut-resistant variety Omar replaced the badly smutting Elmar and became the most widely grown variety in the Pacific Northwest. Because of its high resistance, Brevor had previously replaced much of the Elmar acreage. Consequently, it became the leading minor variety. Elgin, Elmar, and Golden continued to be grown in minor proportions.

In an attempt to increase production of bread wheats in the Pacific Northwest, two highly resistant and high yielding varieties, Columbia and Burt, were released in 1955 and 1956, respectively. Columbia is a hard red winter variety that combines the Turkey and Martin types of resistance. Burt is a hard white winter wheat that combines the Martin and Rio factors with the resistance of Brevor. Neither of these varieties is yet grown on extensive acreages.

Racial Populations: The races identified in 1958-1960 largely reflect the low incidence of bunt in the Pacific Northwest during these 3 years. Race T-6 was still predominant in collections from Elmar. Races T-3 and T-8 were found only occasionally. The new Omar race, T-18, was not identified in any collections made from fields of Omar during these 3 years.

DISCUSSION

In many plant diseases where differential host resistance reflects pathogenic specialization of the pathogen, the least resistant host types usually allow the simplest or weakest pathogenic types to prevail. By contrast, the introduction of new and more resistant hosts serves to screen out and perpetuate new and more complex pathogenic types. Thus, in the case of common bunt of wheat, the simple pathogenic races T-1 and L-1 predominated when highly susceptible varieties were the major varieties grown in the Pacific Northwest from 1900 through 1952.

Although such resistant varieties as Albit, Rex, and Hymar, which are resistant to T-1, were available and grown to a limited extent during this period, they did not enjoy the popularity of Golden and the higher yielding variety Elgin. These resistant varieties did screen out and perpetuate such pathogenic races as T-4, -5, -6, -7, -8, and -14 and L-4, -5, -6, and -7, which were to predominate later when the Martin resistance of these varieties was incorporated into a more desirable agronomic type.

Only after the introduction of varieties with the Turkey and Rio resistance factors were race L-8 and later races T-16 and T-17 encountered in the Pacific Northwest. All three of these races are specialized to these resistance factors. The hard red winter variety Ridit, which was introduced to replace the highly susceptible Turkey varieties, was never grown very widely. However, it screened out four races (T-11, T-13, L-9, and L-10) specialized to this type of resistance. Thus, through 1950 each resistant type introduced had screened out a new pathogenic race while the highly susceptible variety Elgin was perpetuating the relatively weak races T-1 and L-1.

The mounting severity of the smut problem in Elgin dictated the development and release of its backcross derivative Elmar, which is resistant to half the known races, including those occurring on Elgin. In all areas of adaptation, Elmar succeeded in displacing Elgin and all other varieties of lesser yielding capacity. With this intensity of production there came a pronounced increase in the prevalence of the Martin races previously identified from Rex and Hymar, with the result that smut soon became a critical problem in Elmar. In retrospect, the fate of Elmar was inevitable and illustrates the hazard of relying on a single type of specialized germ plasm in controlling smut with resistant varieties. Despite high resistance to many smut races, the doom of Elmar was sealed, in effect, by a single race, T-6.

On the other hand, the critical smut problem in Elmar might not have developed so rapidly had Brevor, its companion variety in release, been more popular. Because Brevor is highly resistant to races that are pathogenic in Elmar, it could have served from the beginning as an effective barrier against the Martin races. Unfortunately, it was not until smut became an acute problem in Elmar that there was a shift to Brevor. Significantly, just as the substitution of Elmar for Elgin had reduced the prevalence of the weaker races T-1 and L-1, the increased acreage of Brevor in 1956 and 1957 did much to decrease the prevalence of Martin smut races.

In the meantime, the rapid build-up of Martin races in the favored variety Elmar created a demand that was met with the introduction of Omar in 1956. Omar is a good-quality, high-yielding, red chaff club wheat that combines the Martin and Turkey resistance factors in one variety which was resistant to all known races at the time of its release. Its production spread rapidly and greatly alleviated the smut problem in the short span of 2 years. During that time, a new race of smut, T-18, which is pathogenic on Omar and all commercial varieties with Omar's type of resistance was identified. Thus, the stage is set for the selective screening and increase of a specialized smut race of these varieties and especially on Omar because of its widespread, intensive production. Racial dynamics in the bunt species is the key factor to the perpetuation of the smut problem in this region.

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POWDERY MILDEW ON PEACH

Harry L. Keil and Roy A. Wilson[1]

Summary

Peach powdery mildew (Podosphaera oxyacanthae (DC.) d By.) developed natural-
ly on potted peach (Prunus persica) plants grown in the greenhouse for study of
bacterial leaf spot. Cross-inoculation of Jonathan apples and peaches produced no
infection. A difference in susceptibility to P. oxyacanthae was shown by various
peach seedlings and one budded variety. Of 28 peach herbarium specimens studied,
93% showed only the conidial stage of powdery mildew.

INTRODUCTION

Two powdery mildew fungi attack peach (P. persica). According to Anderson[2] Sphaero-
theca pannosa Wallr. ex Lév. is very common and P. oxyacanthae much less so. Even though
only the conidial stage of peach mildew is usually present in the field, most investigators ap-
parently do not hesitate to call the fungus by one name or the other; the former is used more
frequently. One wonders how often the chosen name is incorrect when the perfect stage of the
fungus is lacking. Incidental to our other work, certain facts presented herein were discovered
regarding peach powdery mildew. These might help clarify some questions which arise from
time to time concerning this disease.

DISEASE AND FUNGUS

Potted peach seedlings and budded trees grown in a greenhouse through the summer for
bacterial leaf spot inoculation studies became naturally infected with powdery mildew during
the fall and winter. The disease manifest itself first as white patches but eventually covered
entire leaves.   During cloudy periods there were present only small hollow ring-like reddish
spots, up to 1/4 inch in diameter, with very little or no visible mycelium.
Perithecia were found during the fall and winter on all peach varieties studied when green-
house temperatures were maintained at 70° to 75° F. They were always found first on the up-
per leaf surface, but as the disease progressed they were also found on the lower leaf surface.
The appendages were arranged equatorially around the perithecium. Their tips were always
elaborately dichotomously branched; each mature perithecium bore one ascus with eight asco-
spores. These characteristics appear to identify the fungus as P. oxyacanthae.

CROSS-INOCULATION STUDIES

Because apple seedlings held in the same greenhouse showed powdery mildew infection be-
fore the peach plants, it was wondered whether there was some relation between the two dis-
eases. Cross-inoculations with conidia from mildewed peach leaves brushed on leaves of six
Jonathan trees and conidia from mildewed Jonathan apple leaves brushed on leaves of six peach
trees failed to produce infection. However, infection did take place on check trees; that is,
peach leaves inoculated with spores from mildewed peach leaves and apples inoculated with
spores from mildewed apple leaves became infected. | On the basis of the perfect stage these
two fungi on peach and apple, respectively, were later proved to be P. oxyacanthae and Podo-
sphaera leucotricha (Ell. & Ev.) Salm.

VARIETAL SUSCEPTIBILITY

A dozen or more plants of each of eight seedling varieties and of one (Sunhigh) on seedling
rootstock, grown in the same greenhouse, showed striking differences in susceptibility to
natural infection by powdery mildew. The response of the plants within a variety were more or
less uniform. Ranking infection from severe to very slight during the latter part of January

showed that the varieties arranged themselves in the following order: H-98, N.J.-94727, H-58, Elberta, Sunhigh, H-62, F.V.331-52, and Okinawa. The F.V.331-52 and Okinawa seedlings showed only an occasional lesion, indicating they are fairly resistant, whereas H-98 and N.J.-94727 were almost completely covered with mildew. The other varieties ranked in between these two extremes.

HERBARIUM SPECIMENS

As pointed out by Anderson[2], usually only the conidial stage of peach mildew is present in the field. This appears to be borne out by examination of specimens of mildewed P. persica in the National Fungus Collections at Beltsville, Maryland. All 17 specimens submitted by various American and foreign investigators as S. pannosa show only the conidial stage. Furthermore, only 2 of 11 other specimens on the same host, and submitted as P. oxyacanthae, had immature perithecia. Even these could not be identified as to species because the perithecia lacked appendages. Most investigators report powdery mildew on peach as S. pannosa and only a few as P. oxyacanthae. If the herbarium specimens are representative of the mildew stage found occurring on peach in nature, one wonders how many investigators can correctly report a specific powdery mildew.

The fact that P. oxyacanthae was so prevalent in our greenhouse studies on several different varieties may indicate that this fungus might be more common in nature than reported. Seemingly the incidence of two different powdery mildews on peach in nature might be proved by inoculating potted peach plants with conidia from naturally field infected plants and allowing them to grow under conditions which induce production of the perfect stage.

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DEVELOPMENT OF FUSARIUM WILT ON RESISTANT VARIETIES OF TOMATO CAUSED BY A STRAIN DIFFERENT FROM RACE 1 ISOLATES OF FUSARIUM OXYSPORUM F. LYCOPERSICI[1]

Robert E. Stall[2]

Abstract

An outbreak of Fusarium wilt on tomato varieties resistant to race 1 strains of Fusarium oxysporum f. lycopersici was discovered in south Florida. Isolates of Fusarium different from race 1 strains were cultured from diseased plants. All varieties having the Lycopersicum pimpinellifolium Acc. 160 factor for resistance were susceptible to the different isolate. Some tomato lines resistant to race 2 of F. oxysporum f. lycopersici were also resistant to the different strain.

Plants of the tomato varieties Manalucie and STEP 314[3] were found with typical symptoms of Fusarium wilt (Fusarium oxysporum f. lycopersici (Sacc.) Snyder & Hansen) in a routine survey of a tomato farm near Delray Beach, Florida. Yellowed older leaves, unilateral wilting and chlorosis of the plants, and discoloration of the vascular systems were noted. When the disease was discovered plants with external symptoms were concentrated in approximately 5 acres, but diseased plants were scattered throughout about 400 acres. Toward the end of the crop nearly all plants examined had some degree of vascular discoloration.

This discovery was disturbing since Manalucie and STEP 314 have the Lycopersicum pimpinellifolium Mill Acc. 160 factor for resistance described by Bohn and Tucker (4) and are resistant to the common strains of the Fusarium wilt organism. However, varieties with this type of resistance are not resistant to all strains. Alexander and Tucker (3) found an isolate in a greenhouse in Ohio that was pathogenic to plants with the Acc. 160 factor for resistance. This isolate was designated race 2 to distinguish it from the common isolates which were designated race 1.

The occurrence of Fusarium wilt on tomateos in the Delray Beach area is the first instance to the writer's knowledge of the disease causing economic losses in tomato varieties having the Acc. 160 factor for resistance. This paper presents the results of studies which indicate that a strain of the wilt organism involved differs from the common race 1 strains.

CAUSE OF DISEASE

A Fusarium sp. was isolated consistently from the vascular systems of diseased plants. A combination of the Fusarium isolates was inoculated on Indian River and Homestead-24 tomato seedlings by a root-dip method. Inoculum was prepared by mixing agar cultures with 25 ml of distilled water per plate and macerating by means of a Waring Blendor for 2 minutes. Roots of tomato seedlings were dipped in this suspension and planted in virgin Immokalee fine sand that had been limed and fertilized.

Fusarium wilt symptoms developed in all of the inoculated seedlings. These results indicated that the disease at the Delray farm was Fusarium wilt. Furthermore, a different strain of the causal fungus was probably involved since the fungus was virulent on tomato varieties hitherto resistant to the disease.

DIFFERENTIATION AS TO VIRULENCE

Four separate tests for comparison of isolates of Fusarium on varieties of tomato were completed from April 14 to June 9, 1960. In each test seedlings were inoculated by a root-dip method similar to that already described. The technique differed in that cultures were prepared by pipetting 1 ml of a Fusarium suspension into Petri dishes containing about 20 ml of potato-dextrose agar. The suspension was prepared by scraping the surface of a slant culture to which sterile distilled water was added. Cultures were incubated 3 or 4 days before macer-

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ating.

Strains of race 1 and an uninoculated check were included in each test with the Delray isolate. Isolates A and B of race 1 were obtained from Dr. J. M. Walter and are used in routine screening tests for disease resistance. Isolate C was obtained from a susceptible variety at the Indian River Field Laboratory and the Delray isolate was obtained from a diseased STEP 314 plant.

In each test seedlings of several varieties, including Grothen's Red Globe as a standard for susceptibility to race 1, were inoculated before true leaves had started to expand. This was between 7 and 11 days after seeding.

Results were recorded between 10 and 15 days after inoculation. Seedlings were considered diseased if vascular discoloration could be detected. Data were analyzed by the chi-square test in which the percentage of diseased plants in the resistant varieties was used to calculate the expected ratio.

The resistant varieties Manalucie, Indian River, STEP 314, Homestead-24, STEP 89, Jefferson, Marion, STEP 341, STEP 357, Manahill, Manasota, W. R. Brookston, W. R. Jubilee, W. R. Globe and W. R. Seven were inoculated during these tests. There was little difference among these varieties in disease development caused by the race 1 isolates (resistant), or by the Delray isolate (susceptible), so the data with these varieties were combined and were recorded under resistant seedlings (Table 1).

Table 1. Results of tests with different Fusarium isolates on hosts with and without the Acc. 160 factor for resistance.

Tests	Race 1 strains[a]								Delray[a] isolate	
	Isolate A		Isolate B		Isolates A and B		Isolate C			
	res.	sus.[b]	res.	sus.	res.	sus.	res.	sus.	res.	sus.
Test no. 1										
Total tested	160	40	160	40	---	---	160	40	160	40
Diseased	89	38	12	19	---	---	60	36	150	32
% diseased	55.6	95.0	7.5	47.5	---	---	37.5	90.0	90.1	80.0
Test no. 2										
Total tested	320	80	320	80	---	---	320	16	320	80
Diseased	136	76	11	20	---	---	46	16	314	76
% diseased	42.5	95.0	3.4	25.0	---	---	14.4	100.0	98.1	95.0
Test no. 3										
Total tested	120	40	---	---	120	40	120	40	120	40
Diseased	73	39	---	---	38	38	53	38	112	38
% diseased	60.8	97.5	---	---	31.7	95.0	44.2	95.0	93.3	95.0
Test no. 4										
Total tested	334	40	---	---	338	40	304	40	360	40
Diseased	171	39	---	---	146	35	135	40	340	40
% diseased	51.1	87.5	---	---	43.1	87.5	44.4	100.0	94.0	100.0
Total of all tests										
Total tested	934	200	480	120	458	80	904	136	960	200
Diseased	469	192	23	39	184	73	294	130	916	186
% diseased	50.2	96.0	4.8	32.5	40.2	91.3	32.5	95.6	95.4	93.0

[a]Isolate A, Fusarium oxysporum f. lycopersici #43.01 obtained from J. M. Walter; Isolate B, F. oxysporum f. retusum Wellman #46.01a obtained from J. M. Walter; Isolate C, Fusarium sp., from wilted Grothen's Red Globe at Indian River Field Laboratory; Delray isolate, Fusarium sp., from wilted STEP 314 plant near Delray Beach, Florida.
[b]Res.-Resistant varieties include: Manalucie, Indian River, STEP 314, Homestead-24 and STEP 89, Jefferson, Marion, STEP 341, STEP 357, Manahill, Manasota, W. R. Brookston, W. R. Jubilee, W. R. Globe and W. R. Seven. Sus.-Susceptible variety was Grothen's Red Globe.

There were significant differences in virulence among the race 1 isolates on the resistant seedlings. However, the Delray isolate was highly significantly more virulent (P=<.01) than any of the race 1 isolates on the resistant hosts. Probably of more meaning, there were highly significant differences (P=<.01) between the resistant seedlings versus the susceptible seedlings with each of the race 1 isolates but not with the Delray isolate. The varieties bred for

resistance to race 1 were as susceptible to the Delray isolate as was Grothen's Red Globe.

The high incidence of disease development on the varieties resistant to race 1 when inoculated with the race 1 strains means that these tests were very severe. High temperatures (air temperatures ranged from 66° to 107°F, with maximum temperatures only occasionally below 100°) and a high inoculum potential probably contributed to this situation.

DIFFERENTIATION AS TO QUALITATIVE PATHOGENICITY

Another trial was completed in which some plant introduction accessions which Alexander (1) and Alexander and Hoover (2) found to be resistant to race 2 were inoculated with the Delray isolate. The inoculum potential was reduced to half of that previously used. The disease incidence on the resistant seedlings in this test was more in line with that obtained by other workers.

Results of this test differentiated the Delray isolate from the strains of race 1 in qualitative pathogenicity as well as virulence (Table 2). The Delray isolate was more severe on Mana-

Table 2. Disease development on race 2 resistant tomato lines inoculated with the Delray isolate and race 1 strains of F. oxysporum f. lycopersici.

Species and varieties	Race 1 strains		Delray isolate
	Isolate A and B[a]	Isolate C	
L. esculentum var.			
Manalucie (exp. control)	2[b]	2	5
L. esc. x L. pimp.			
P.I. 129135	5	5	3
L. pimpinellifolium			
P.I. 212409	3	3	4
P.I. 212408	2	2	2
P.I. 211840	2	2	2
L. peruvianum			
P.I. 212407	2	2	2
P.I. 126944	2	2	1
P.I. 126928	2	2	2
P.I. 126945	2	2	2

[a]Isolates are same as in Table 1.

[b]Ratings were based on a population of 40 seedlings. Rated on a 1-5 basis, where: 1 = no symptoms; 3 = slight to moderate symptoms, usually dying slowly; 5 = severe symptoms followed by rapid death; 2 = plants of classes 1, 3 and/or 5; 4 = a mixture of classes 3 and 5.
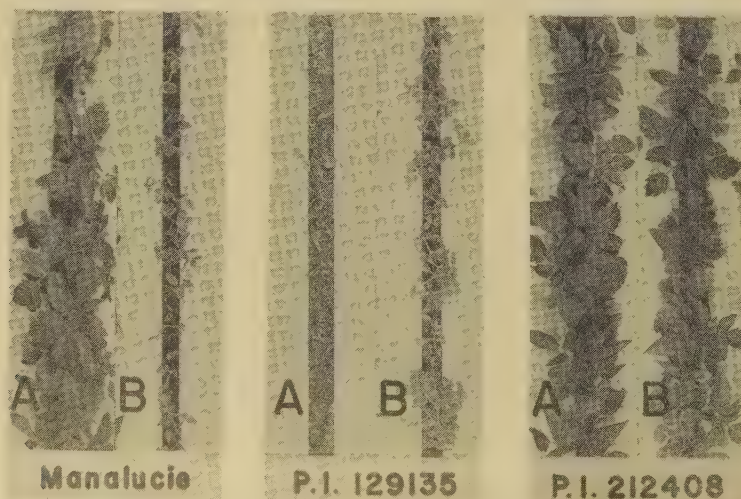

FIGURE 1. Development of Fusarium wilt on three tomato stocks following inoculation with the race 1 (A) and Delray (B) isolates of Fusarium.

lucie than the race 1 strains, but the latter were more severe on P.I. 129135 than the Delray
isolate (Fig. 1). P.I. accessions 211840 and 212408 might be useful as sources of resistance.

Most of the P.I. accessions selected for resistance to race 2 were also resistant to the
Delray isolate. However, an isolate of race 2 and the Delray isolate should be compared in
the same test before conclusions are drawn as to whether they are of the same biotype.

<div align="center">DISCUSSION</div>

L. pimpinellifolium Acc. 160 and its resistant progeny are not immune to the race 1
strains of the Fusarium wilt organism (3, 5). Thus, plants diseased by the common strains
can be found in the field. However, these diseased plants are infrequent and are not often
noticed. This is in marked contrast to the amount of disease that developed at the Delray farm.
A strain of Fusarium different from race 1 probably was the cause of the abnormal amount of
diseased plants.

Pathogenic differences among isolates of this fungus have been reported by many workers
(3, 5, 6). However, since the resistance in Acc. 160 was described by Bohn and Tucker (4) in
1939 only two instances of isolation of types pathogenic to plants with this resistance factor are
recorded. In addition to Alexander and Tucker (3), Gerdemann and Finley (5) reported isolat-
ing such types. The latter were working with the Alexander and Tucker isolate, however, and
were not certain that the cultures isolated had not been introduced from some outside source.

In spite of the existence of race 2 strains, these apparently have not increased to the point
of causing economic losses. Dr. Alexander, in personal correspondence, wrote that he knows
of no "build-up" of any race other than the widely distributed race 1 in Ohio. It was learned
in discussions with Dr. R. A. Conover and Dr. J. M. Walter that increases in Fusarium wilt
on the resistant varieties in the Homestead and Bradenton areas of Florida have not been no-
ticed. The farm at Delray has been surveyed routinely for the past 3 years and the spring of
1960 was the first time that Fusarium wilt has been seen. An increase of Fusarium wilt has
not been found on other farms in the Delray area.

Since the only satisfactory method of control of Fusarium wilt has been the development of
resistant varieties, widespread dissemination of this different type of Fusarium would nullify
effective control of the disease. If this strain can survive and compete with other soil inhabi-
tants similar to the common race 1 types, then rapid spread probably can be expected.

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A BACTERIAL LEAF SPOT OF FLORISTS' CHRYSANTHEMUMS, CHRYSANTHEMUM MORIFOLIUM[1]

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Summary

A bacterial leaf spot disease of Chrysanthemum morifolium was first observed in 1957 near Stuart, Florida. The spots are characterized as dark brown to black, slightly sunken, and exhibit concentric zonations. Infection is highly dependent upon high moisture and leaf maturity. Cultural, morphological and biochemical studies as well as cross-inoculation tests have shown the pathogen to be similar, with few exceptions, to Pseudomonas cichorii (Swingle) Stapp. Control was satisfactory on susceptible varieties during rainy weather using weekly foliar sprays of either Tribasic Copper Sulfate or Agri-mycin 500.

INTRODUCTION

In 1957 a leaf spot disease was first observed causing damage to stock plantings of Chrysanthemum morifolium var. Bluechip in Stuart, Florida. The spots, usually first evident on the lower foliage, were unlike those of any previously recognized chrysanthemum disease. Congo Red smear preparations made from infected tissues revealed the presence of large numbers of bacteria. Laboratory isolation consistently yielded a bacterium, which when introduced into healthy leaves produced leaf symptoms indistinguishable from natural infections.

Except for brief reports by McFadden (5, 6) no mention of the disease has been found in the literature. Stapp (8) in 1932 described a leaf spot disease of Chrysanthemum indicum caused by Pseudomonas syringae van Hall, which resembles in many respects the disease reported here. Williams (9) in 1927 briefly described a bacterial disease which caused a drooping of the blooms and a hollowness of the stalk immediately below the calyx. Williams did not name the pathogen but considered it closely related to Xanthomonas vesicatoria (Doidge) Dowson. Septoria leaf spot (Septoria sp.), Ascochyta leaf blight (Ascochyta chrysanthemi Stevens), Botrytis leaf blight (Botrytis cinerea Pers.) and bacterial blight (Erwinia chrysanthemi Burk. et al.) also occur on chrysanthemums in Florida.

SYMPTOMS

Leaf Symptoms: The disease usually attacks the lower, older leaves first but may eventually blight the top leaves and flower buds as the plant matures. In new plantings the disease often appears 4 to 5 weeks after planting. The spots are more or less circular to elliptical at first, measuring only a few millimeters in diameter but later may increase in size to approximately 1 cm. Several lesions may coalesce to form large, irregular necrotic areas on the leaf. Under continued moist or wet conditions the disease may also develop along the leaf margins. The lesions are dark brown to black. When moist, the spots are soft and mushy but, when dry, they are slightly sunken and brittle, and show characteristic zonations. Often the centers of the spots fall away leaving areas resembling those eaten by certain insects. A clear line of demarcation, without yellowing, separates diseased from healthy tissue (Fig. 1).

Bud and Stem Symptoms: Occasionally leaf infections spread down the petiole and cause a dark brown to black stem necrosis which results in a blighting of the parts above. If the disease is not controlled on the foliage, flower bud infections often result. The buds turn dark brown to black, and the necrosis usually extends down the stem for approximately 1 to 2 inches. Affected buds wither and die prematurely, much as they do in Ascochyta flower blight (Fig. 2).

PLANT INOCULATIONS

When plants of Iceberg and Bluechip chrysanthemums were sprayed with a water suspension of the pathogen using a No. 15 DeVilbiss atomizer, relatively few infections resulted. A

FIGURE 1. Symptoms of bacterial leaf spot of chrysanthemum (var. Bluechip) at left; healthy leaf at extreme right.

FIGURE 2. Symptoms of bacterial bud blight infections of chrysanthemum (var. Iceberg) at right; healthy flower bud at extreme left.

large number of leaf lesions developed, however, when similar plants were inoculated with a bacterial suspension using an atomizer having air pressure of 30 p.s.i. Leaves which were first water-soaked and then inoculated routinely developed numerous lesions. The varieties Bronze Delaware, Snowclad, Quicksilver, and Personality all developed typical leaf spots when a sharp scalpel contaminated with the pathogen was inserted into leaf blades and petioles. A severe blight developed in the varieties Delaware and Iceberg when the buds, or the stems immediately below the buds, were artificially inoculated. Likewise, a necrosis developed when stems were inoculated using a scalpel contaminated with the bacterium. Tip cuttings of Iceberg chrysanthemums were not blighted when inoculated by placing their cut ends in a suspension of the pathogen, even though a superficial brown to black necrosis developed on the basal stem.

Many varieties of chrysanthemum grown commercially in Florida are susceptible to some degree. Relatively few, however, are highly susceptible. Those most commonly attacked include Bluechip, Iceberg, Shasta, Indianapolis and Delaware.

CONDITIONS FAVORING THE DISEASE

Moisture appears to be the most important factor for infection. Disease incidence under natural conditions coincides with heavy and frequent rains. Extended periods of rain, which often results in a water-soaking of leaves, favor infections. Localized spread of the pathogen is primarily due to irrigation water or splashing rains. Temperature effects on the disease have not been investigated but they appear less critical than water relationships, since the disease may be found in south Florida throughout the year. The disease is believed to be disseminated on cuttings even though no lesions may be observable at planting time.

THE PATHOGEN

The pathogen was readily isolated from both stem and bud lesions. Six isolates of equal pathogenicity were selected for further study. All isolates reacted in a similar manner in the various morphological, cultural, and biochemical tests performed. Frequent dilutions were made of each isolate, and single colonies selected to aid in maintaining their purity. The carbohydrates were filter sterilized and employed at 1% concentration unless otherwise stated, and the organic acids at 0.15%. The methods and procedures followed were essentially those suggested elsewhere (2, 3, 7).

Morphology: The pathogen is a short rod with rounded ends occuring singly or in pairs, occasionally in chains of 3 to 8. Cells from a 24-hour culture on Bacto nutrient agar measured $2.4 \times 0.9\mu$ ($1.4-3.2 \times 0.7-1.1\mu$). The bacterium is Gram-negative, and exhibits 2 to 6 polar flagella when stained by the Leifson method (4).

Cultural Characteristics: Twenty-four-hour colonies grown on freshly prepared potato-glucose agar were grey-white with smooth, shiny surface and wavy margins. Colonies grow-

Table 1. Comparison of biochemical reactions of three species of Pseudomonas with the chrysanthemum pathogen.

Test or medium	P. syringae[a]	P. calendulae[a]	P. cichorii	Chrysanthemum pathogen
Gelatin liquefaction	+	-	-	-
Starch hydrolysis	-	-	-	-
Indole	-	f	-	-
Methyl Red			-	-
Voges-Proskauer			-	-
Nitrite from nitrate	-	-	-	+[c]
H$_2$S production	-	-	-	-
Lipolytic activity	-		+[b]	+
Milk	a	nc	a, nc	a, nc
Koser citrate			+	+
NaCl 5%			+	+
Pigment production in culture	+	+	+	+
Arabinose	A		A	A
Rhamnose	-		fA[b]	fA
Xylose	A		A	A
Glucose	A	A	A	A
Fructose			A	A
Galactose	A		A	A
Mannose	A		A	A
Glycerol	A	A	A	A
Mannitol	A		A	A
Melibiose			-	-
Lactose	-	-	-	-
Sucrose	A	-	-	-
Maltose	-		-	-
Raffinose	-		-	-
Dextrin			-	-
Sorbitol			fA	A
Dulcitol			-	-
Ethyl alcohol			A	fA
Cellobiose			-	-
Inulin			-	-
Salicin	-		-	-
Sodium citrate	a		a	a
Sodium tartrate	-		a	a

[a]Description from Bergey's Manual of Determinative Bacteriology.
[b]Variation from description given in Bergey's Manual of Determinative Bacteriology.
[c]Some isolates strongly positive, others feeble.
+positive or utilized, - negative or not utilized, f feeble, a alkaline reaction, A acid formed, nc not coagulated.

ing on Bacto nutrient agar were greyish white, raised, and filiform with wavy margins. The cultures became slightly buff colored with age. Bacto nutrient broth supported good growth with the formation of a heavy pellicle. Growth in Clara's medium, containing asparagine, was moderate with the formation of a green fluorescent pigment. No turbidity resulted in Fermi's solution, whereas good growth was noted in Koser citrate medium. Litmus milk was both partially reduced and peptonized, and the medium turned alkaline.

Growth on Endo agar was reddish, and the medium turned yellow in 5 days. Krumwiede's triple sugar agar turned red in 1 week. Colonies of the bacterium grown on Bacto eosin methylene blue agar were bluish-pink, whereas on desoxycholate agar they were pale pink.

Biochemical Characteristics: Several biochemical tests were performed on the chrysanthemum leaf spot pathogen. The results of these tests are summarized in Table 1, and a comparison is made with three known species of Pseudomonas.

Cross-inoculation Tests: In early tests the pathogen was noted to belong in the genus Pseudomonas, and certain biochemical similarities occurred between it and other described species. Two cultures of P. syringae (PS 169, PS 170), and one of P. cichorii (PC 26), were

obtained from W. H. Burkholder, Cornell University for cross-inoculation studies. The chrysanthemum organism produced a rot of chicory, romaine, head and leaf lettuce, and of cabbage, pepper and onion. A slight rot of potato tubers was observed after 2 days in a moist chamber. The culture of Pseudomonas cichorii proved pathogenic to leaves and buds of Iceberg, Bluechip and Delaware chrysanthemums, producing symptoms similar to those initiated by the chrysanthemum isolates, whereas P. syringae was unable to infect these varieties. It was not possible to obtain a culture of P. calendulae (Takimoto) Dowson for cross-inoculation purposes. Cultures of the chrysanthemum organism and P. cichorii both caused a mild infection of young seedlings of Calendula officinalis.

Taxonomy: The chrysanthemum leaf spot bacterium fits well into the genus Pseudomonas Migula, since it was shown to be a Gram-negative, non-spore forming rod with polar flagella (1). Its ability to produce a green fluorescent pigment in Clara's solution and its inability to utilize lactose, sucrose, salicin, and maltose further substantiate these conclusions. When compared with other species of Pseudomonas in the various cultural, morphological and biochemical tests, the chrysanthemum pathogen showed a closer relationship to P. cichorii and P. calendulae than to P. syringae. It differed from P. cichorii in that the latter failed to reduce nitrate to nitrite, and to produce a fluid turbidity in either Fermi's solution or Ayers, Rupp, and Johnson medium containing ammonium salts and glucose. Pseudomonas calendulae reportedly differs from the chrysanthemum organism in its negative nitrite test, and its feeble test for indole. Since a culture of this organism was not available, further comparisons were not possible.

A close similarity exists between the chrysanthemum pathogen and P. cichorii in cross-inoculation studies and in a large number of cultural and biochemical tests. For these reasons the leaf spot pathogen is considered to be P. cichorii.

CONTROL

In replicated treatments, sprays were applied to plants of Iceberg and Bluechip chrysanthemums grown in outdoor beds provided with overhead irrigation. Weekly sprays of Tribasic Copper Sulfate at 4 pounds/100 gallons, and Agri-mycin 500 (10% streptomycin sulfate, 1% oxytetracycline, + basic copper sulfate) at 3 pounds/100 gallons gave highly satisfactory control without apparent injury to foliage or open flowers. Agri-Strep (streptomycin sulfate) and Agri-mycin 100 (15% streptomycin sulfate, 1.5% oxytetracycline) both at 60 ppm (active ingredient) were slightly less effective and caused faint yellowing of the foliage when used over an extended period. A high incidence of disease occurred in the control plants. Stock plants of susceptible varieties should be sprayed weekly with Tribasic Copper Sulfate during rainy periods under south Florida conditions. Such a program has been in practice for 2 years by several commercial growers and highly satisfactory results have been obtained.

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NEMATODE POPULATIONS ASSOCIATED WITH CITRUS ROOTS IN CENTRAL FLORIDA[1]

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Summary

A survey of citrus groves in central Florida was made to ascertain the kinds and numbers of root-parasitic nematodes present and to attempt to evaluate their effects on citrus trees.

A total of 343 samples were collected from 64 groves in 15 citrus-producing counties. Most groves surveyed were in excellent growing condition, a few had declining trees, and all groves contained plant parasitic nematodes.

Nematodes most frequently occurring were Aphelenchus avenae, Trichodorus spp., Tylenchulus semipenetrans, Xiphinema spp., Belonolaimus spp., Diphtherophora spp., and Hoplolaimus tylenchiformis, in the order mentioned. Nematodes less frequently occurring, but still relatively common in occurrence, were Pratylenchus spp., Hemicycliophora spp., Helicotylenchus nannus, Meloidogyne spp. Genera seldom found were Criconemoides, Tylenchorhynchus, Longidorus, Hemicriconemoides, and Scutellonema. In total, 35 stylet-bearing genera were identified.

Some edaphic factors were found associated with the distribution and intensity of population for some species. A characteristic declining condition of trees in the Vero Beach-Fort Pierce area was associated with high populations of Xiphinema americanum and Trichodorus spp. In the same area, where a 2-week period of inundation had resulted from heavy rains, Tylenchulus semipenetrans was judged to be a contributing factor in the death of some trees.

INTRODUCTION

Most of the information concerning plant parasitic nematodes capable of injuring citrus roots in Florida has been derived from surveys of spreading decline of citrus caused by Radopholus similis (Cobb) Thorne. Few intensive studies have been undertaken on the role played by phytoparasitic nematodes, other than the burrowing nematode, in citrus groves. The dearth of information on the kinds, frequency of occurrence, and distribution of the nematodes associated with citrus roots in Florida motivated this survey. In particular, it was hoped to gain a better knowledge of the distribution of ectoparasitic nematodes in Florida citrus groves. Such forms are generally overlooked by spreading decline survey workers, who, as a rule, deal only with root-endoparasitic nematodes.

The importance of ectoparasitic nematodes has been emphasized by several investigators. Christie (5) states that ectoparasitic species probably attain their greatest detrimental importance in subtropical and tropical regions.

MATERIALS AND METHODS

Sixty-four groves were sampled during the course of this study, most of which were checked monthly by the Citrus Insect and Disease Survey Program, Citrus Experiment Station, Lake Alfred, Florida. A majority of these groves were in good growing condition.

The citrus groves surveyed were budded on the following rootstocks: sour orange, rough lemon, Cleopatra mandarin, and grapefruit. Sixty-three % of the groves were comprised of trees growing on sour orange, 33% were on rough lemon, and the remainder were on Cleopatra mandarin or grapefruit.

Roots and soil samples were collected from five trees in each grove. Trees ranged in age from 14 to 59 years and were growing in a variety of soil types, from the fine sandy loams of Polk County to the marly, high organic soils of the Vero Beach-Fort Pierce area. A composite sample consisting of 1 pint of feeder roots and soil was taken from opposite sides of the "drip zone" of each tree, usually at a depth of 6 to 18 inches. Samples were sealed in poly-

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Table 1.   Stylet-bearing nematodes found associated with citrus roots in central Florida.

Nematodes previously reported associated with citrus roots in Florida	Nematodes not previously found associated with citrus roots in Florida
Aphelenchus avenae	Criconemoides ornatum
Belonolaimus gracilis	Diphtherophora obesus
Belonolaimus longicaudatus	Diphtherophora perplexans
Dorylaimellus nodochordus	Helicotylenchus nannus
Hemicycliophora parvana	Hemicriconemoides wessoni
Hoplolaimus tylenchiformis	Hemicycliophora similis
Leptonchus granulosus	Longidorus elongatus
Pratylenchus brachyurus	Scutellonema brachyurum
Pratylenchus zeae	Trichodorus aequalis
Pseudhalenchus anchilisposomus	Trichodorus porosus
Pungentus textilis	Trichodorus proximus
Seinura mali	Tylenchorhynchus acti
Trichodorus christiei	Xiphinema campinense
Tylenchulus semipenetrans	Xiphinema chambersi
Xiphinema americanum	

ethylene plastic bags and kept no longer than 8 days (15). All samples were processed by the elutriation method of Tarjan, et al. as described by Malo (10). Plant parasitic nematodes obtained by this technique were identified by mounting them either in lactophenol or glycerine, using the Baker technique (2). Nichrome wire was used as cover slip supports (4). The number of nematodes was estimated and an index was used for their quantitative recording.

RESULTS

A list of the nematodes found associated with citrus roots in the groves surveyed is presented in Table 1.

Only Tylenchulus semipenetrans Cobb, 1913, Xiphinema americanum Cobb, 1913, and Trichodorus spp. Cobb, 1913 were found in association with declining trees.

Aphelenchus avenae Bastian, 1865, the nematode most commonly found, was present in 74% of the samples collected. Although this nematode was well distributed in all areas sampled, it was present in higher numbers in organic soils. The status of this nematode as a root parasite is dubious (8, 14). It is known to feed on pathogenic root fungi (12) as well as on decaying organic matter (14); but, the possibility exists that it feeds on citrus roots when the preferred food is virtually non-existent.

Trichodorus spp. were the plant parasites occurring most commonly; they were present in 30% of the samples. Trichodorus christiei Allen, 1957 was the predominant species. The distribution of these nematodes was uniform in the areas sampled. Trichodorus spp. and Xiphinema americanum were present in unusually high numbers in certain groves which exhibited declining symptoms (whose primary cause is unknown) in the Vero Beach-Fort Pierce area. This area is characterized by a marly, high organic sandy soil and a high water table.

Specific aboveground symptoms caused by the citrus nematode, Tylenchulus semipenetrans Cobb, 1913 were not generally evident despite its occurrence in 26% of the samples, a distribution in accord with recent evidence (9). A possible exception occurred in one grove in the Vero Beach-Fort Pierce area, where the nematode was strongly suspected as contributing to the cause of death of 30-year-old grapefruit trees after a 2-week period of inundation.

Dagger nematodes, Xiphinema Cobb, 1913, were most frequently found on the East Coast of Florida, from DeLand to Fort Pierce. These ectoparasites occurred in 20% of the samples taken. Xiphinema americanum was the predominant species. An unidentified species of Xiphinema was collected on Merritt Island.

The sting nematode Belonolaimus longicaudatus Rau, 1958 was more frequently encountered than B. gracilis Steiner, 1949. The incidence of these forms was higher in fine sandy soils where they are likely to cause injury to crops (6). In this survey they were also found in a few groves having a high organic soil.

Although sting nematodes definitely do injure citrus trees (13), no noticeable decline symptoms were observed at the time of sampling.

Root-lesion or meadow nematodes, Pratylenchus Filipjev, 1934, were not commonly encountered. When found, they were always in low numbers. Pratylenchus brachyurus (Godfrey, 1929) Filipjev & Schuurmans Stekhoven, 1941 and Pratylenchus zeae Graham, 1951 were the only two species found, of which the former was most prevalent.

The lance nematode Hoplolaimus tylenchiformis Daday, 1905 was encountered in 12% of the samples collected. Although it is known to penetrate and reproduce in citrus roots, no evidence of its damage was found in this survey.

The occurrence of ring nematodes, Criconemoides Taylor, 1936, and the sheathoid nematode, Hemicriconemoides Chitwood & Birchfield, 1957, was sporadic. When found, both genera existed in low numbers. Only C. ornatum Raski, 1958 and H. wessoni Chitwood & Birchfield, 1957 were identified.

The sheath nematodes Hemicycliophora parvana Tarjan, 1952 and H. similis Thorne, 1955 were the only members of this genus encountered; H. parvana was the predominant species and generally associated with high organic and marly soils. Hemicycliophora arenaria Raski, 1958, which is pathogenic to rough lemon in California (16), was not observed in any of the samples. There is no evidence indicating that H. parvana is pathogenic to citrus in Florida.

Members of the genus Diphtherophora de Man, 1880 appeared to be common associates of citrus roots. Diphtherophora obesus Thorne, 1939 was more common than D. perplexans (Cobb, 1913) Micoletzky, 1922. The last species was described by Cobb (7) from soil around citrus trees at Valencia, Spain and from "pasture plants" at Arlington, Virginia. These nematodes were usually found associated with Trichodorus spp. Their phytoparasitic status is unknown.

Despite the belief that members of the root-knot genus Meloidogyne Goeldi, 1887 are not usually parasitic on citrus roots, there have been several instances in which evidence to the contrary has been found (3, 11, 17). Although no conspicuous symptoms of galling were observed in this survey, several Meloidogyne males and larvae were collected on different occasions.

Members of the superfamily Dorylaimoidea were commonly encountered in all samples examined. By far the most common were Dorylaimus spp., Discolaimus spp., Pungentus spp., and Aporcelaimus spp., in the order given.

None of the nematodes studied were found to show special preference for any of the above-mentioned rootstocks. This, in part, is in contrast to the findings of Baines, et al. (1), who claimed that rough lemon showed a certain degree of resistance to attack from Criconemoides spp. and Pratylenchus spp. In the present study, 7 out of 10 groves from which Criconemoides ornatum was obtained were growing on rough lemon stock. The same relationship existed for species of Pratylenchus.

Table 2. Nematodes found in three general types of Florida soils.

Nematodes usually found associated with high organic soils	Nematodes found associated with sandy and high organic soils	Nematodes usually found associated with sandy soils
Helicotylenchus nannus Hemicycliophora spp.	Aphelenchus avenae Belonolaimus spp. Diphtherophora spp. Hoplolaimus tylenchiformis Trichodorus spp. Tylenchulus semipenetrans Xiphinema spp.	Criconemoides ornatum Pratylenchus spp.

There is considerable evidence that certain nematode species thrive better in certain kinds of soils than in others; the burrowing nematode, Radopholus similis, is a good example. The majority of citrus groves affected by this nematode in Florida are located in soil characterized by being deep, sandy, and having a low organic matter content. Table 2 presents data on the association of certain nematodes with three general types of Florida soils as found in this survey.

No striking relationship was found between the ages of the groves surveyed and the kinds and quantities of nematodes obtained from them. Saprobic nematodes were more abundant in older groves, presumably because earlier planted groves were in soils of a higher organic matter content.

DISCUSSION

The economic importance of the citrus nematode _Tylenchulus semipenetrans_ in Florida citrus groves thus far has not been clearly evaluated. This nematode seems to be uniformly distributed over the citrus-producing areas of Florida as previously suspected (9). High populations were obtained from dying trees in a grove that had been inundated for a 2-week period. Prior to sampling the trees had been examined, with negative results, for evidences of any lethal factor other than nematodes that could have caused the condition[3]. Interpretation of these data is open to speculation. One thesis could well be that this condition was caused by high population of the citrus nematode, coupled with poor drainage.

The citrus nematode eventually may be recognized as a major pest of citrus in Florida when virgin soils for new groves become scarce and replanting is necessarily made on old infested citrus land.

Experiences in California show that replanting of old grove sites drastically retards growth and production of the new trees due to the high populations of citrus nematodes that have built up over the years.

The ectoparasitic nematodes _Xiphinema americanum_ and _Trichodorus_ spp. appear to be common parasites of citrus (1). The association of high populations of these two nematodes with declining groves in the Vero Beach-Fort Pierce area coupled with poor drainage could be responsible for the sudden decline of trees. Here again one can only speculate that the declining symptoms occur only in those trees about which the nematode populations have increased sufficiently to affect the shallow root systems on which the trees depend.

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VERTICILLIUM WILT OF SMOKE BUSH[1]

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Abstract

Smoke bush plants were separately inoculated with Verticillium albo-atrum isolated from eggplant, Norway maple, potato, smoke bush, and tomato. Artificially inoculated plants exhibited similar foliage symptoms and sapwood discoloration regardless of the source of the inoculum. The pathogen was isolated from the soil in the vicinity of a nursery plot with diseased smoke bush.

A wilt disease of smoke bush (Cotinus coggygria) has become increasingly noticeable in Rhode Island. In one nursery planting about 40% of the plants were infected in 1957 and 20% more in 1958. The fungus Verticillium albo-atrum Reinke & Berth. was consistently isolated from diseased sapwood plated on Czapek's nutrient agar medium.

Although Verticillium has been reported to be associated with a wilt disease of smoke bush (1, 2, 4, 5), there has been no mention of tests conducted to prove pathogenicity. The object of the present investigation, therefore, was to prove Koch's postulate of pathogenicity using the fungus isolated from smoke bush, and to determine whether this plant was susceptible to Verticillium albo-atrum isolated from other plant genera.

MATERIALS AND METHODS

Thirty 3-year-old smoke bush plants, established for one growing season, were selected at random and divided into six groups of five plants each. On June 20, 1958 five groups were each separately inoculated with Verticillium albo-atrum isolated from smoke bush, eggplant (Solanum melongena), Norway maple (Acer platanoides), potato (Solanum tuberosum), and tomato (Lycopersicon esculentum). Inoculations were accomplished by inserting a disk of Czapek's 2% agar medium containing a 21-day-old culture of the fungus into vertical wounds made in the sapwood with a scalpel previously dipped in alcohol. Drying out of the fungus was reduced by a covering of moist absorbent cotton secured by a strip of masking tape. The inoculum was selected from colonies that had an abundance of hyphae and microsclerotia. Five trees were similarly wounded, but only sterile agar disks were inserted.

Progress of the disease, expressed as wilt symptoms (estimated as percentage of crown of tree) and sapwood discoloration, was observed. On October 31, 1958 tissue sections from all trees were plated on Czapek's 2% medium for re-isolation of the fungus. On this date two trees of each group were cut down to determine the type and extensiveness of sapwood discoloration.

Isolations of the fungus from soil were made in 1958 and 1959 by employing the potato tuber (1) and alcohol-agar medium techniques (3). Ten scattered soil borings 1 foot deep were taken from a commercial nursery plot in which diseased smoke bush plants were growing. Samples were pooled and from this composite a 2-gram sample was tested. Soil samples were taken in an area of the field at least 20 feet away from the nearest plant exhibiting symptoms of the disease.

DISCUSSION OF RESULTS

Results of the inoculation tests are recorded in Table 1. These data show that in each group there is little difference in (a) the number of trees diseased and exhibiting sapwood discoloration, and (b) the average wilt symptoms regardless of the source of inoculum. Only two trees did not display foliar symptoms and did not yield the fungus when re-isolation was attempted.

All diseased trees behaved similarly in their foliar symptom expressions during the summer months. At the onset of wilt, the leaf margins displayed a characteristic reddish-purple color which progressed inwardly and in some cases completely covered the leaves. The general appearance of the affected foliage was reminiscent of autumnal coloration. Subsequently, the leaf margins turned brown and curled inwardly. Affected leaves of most trees dropped prematurely and trees with brown leaves attached appeared as though scorched.

Sapwood discoloration appeared as dark or reddish-brown streaks or flecks and were usually extensive (Fig. 1).

Table 1. Response of smoke bush inoculated June 20, 1958 with various isolates of Verticillium albo-atrum.

Inoculation source	No. trees inoculated[a]	Wilt symptoms				Total trees showing wilt	Positive reisolation no. trees
		July 14		August 3			
		No. trees	Aver-age %	No. trees	Aver-age %		
Eggplant	5	4	7.5	4	12.5	4	4
Maple	5	2	10.0	4	15	4	4
Potato	5	4	5.0	5	17	5	5
Smoke bush	5	3	11.6	5	20	5	5
Tomato	5	3	6.6	5	15	5	5

[a]Trees used for control were inoculated with sterile agar and did not yield the fungus.
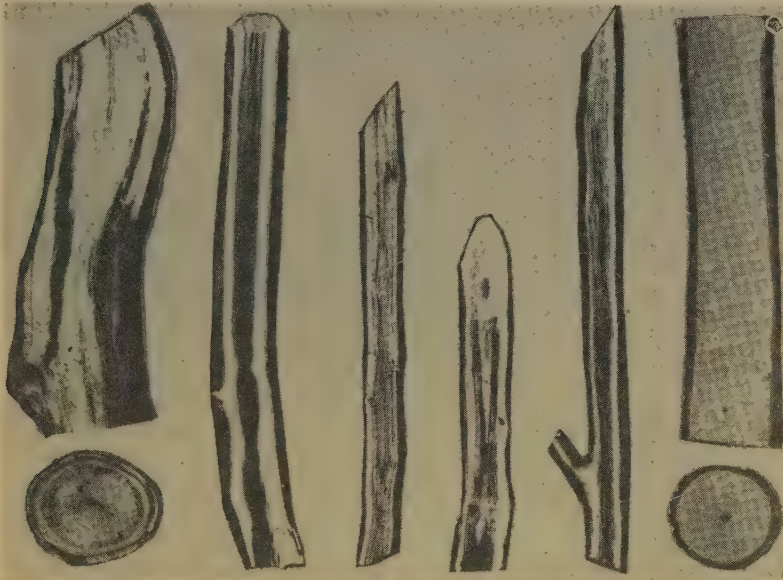
FIGURE 1. Longitudinal and cross-sections of infected and uninfected smoke bush plants. The first five sections from left to right show typical sapwood discoloration of plants inoculated with V. albo-atrum isolated from smoke bush, eggplant, Norway maple, tomato and potato, respectively. The sections at the extreme right were made from controls inoculated with sterile nutrient agar.

Verticillium is present in almost any planting of potato in which a number of varieties are included. Since diseased smoke bush plants in a commercial nursery were located in a field plot previously planted to potatoes, it was speculated that the source of inoculum may have been present in the soil. Positive soil isolations lend support to the belief that the pathogen in the soil may have been responsible for the outbreak of the disease in this particular stand.

Under conditions of this experiment it has been shown that the Verticillium albo-atrum isolates studied do not display any host specificity. It is possible, therefore, that under proper conditions isolates of this fungus from one plant genus are capable of infecting species of the same and different genera.

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OCCURRENCE OF DITYLENCHUS RADICICOLA (NEMATODA: TYLENCHIDAE) IN THE UNITED STATES AND ON A NEW HOST[1]

G. J. Stessel[2] and A. Morgan Golden[3]

Summary

The plant-parasitic nematode Ditylenchus radicicola (Greeff, 1872) Filipjev, 1936 was found in October 1960 inducing galls on roots of Ammophila breviligulata , American beachgrass, along a 20-mile stretch of the southern coast of Rhode Island. Galled roots were first found in May 1960 at Galilee, Rhode Island and the disease incitant was identified in July 1960. This is apparently the first reported occurrence of D. radicicola in the United States and on American beachgrass. On American beachgrass usually lemon-shaped galls were formed primarily at the tips of branch roots. The "grass root-gall nematode" is proposed as a common name for this parasite.

The plant-parasitic nematode Ditylenchus radicicola (Greeff, 1872) Filipjev, 1936 causes galls on the roots of many grasses and cereals in several countries. Its history, life cycle, and other aspects were given in 1933 by Goodey (4) and also discussed later by Filipjev and Schuurmans Stekhoven (1). Briefly, as reviewed by Goodey (4), this nematode was reported by Greeff in 1864 on annual meadow grass and couch grass in Germany. It was next found on Elymus arenarius in Denmark in 1879 and on the same host in Scotland in 1881. In 1885, D. radicicola was noted on barley in both Sweden and Norway. Further reports showed it to be in Finland and also in England where oats, rye, wheat, timothy and some other grasses were susceptible.

Until 1948 D. radicicola was definitely known only in European countries. At that time, however, it was reported by Vanterpool (6) on wheat in Saskatchewan, Canada and on certain other cereals and grasses experimentally infected. Later, in 1953, the nematode was found in the Netherlands by Oostenbrink (5) on 11 different grasses, 7 of which were new hosts. More recently it was noted on another new grass host in England by Goodey (2). Thus, prior to the present paper, D. radicicola had been reported to attack over 20 species of plants. All of these except two (Sedum sp. and Dodartia orientalis (4) are in the Gramineae. It has been found in Canada, eight European countries and, according to Goodey (2), also in Argentina.

On May 25, 1960, plants of Ammophila breviligulata (American beachgrass) containing numerous galls on their roots were received from a sand marsh area bordering a wild-life

FIGURE 1. General view of nematode-infested stand of American beachgrass at Galilee, Rhode Island, August 1960.

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refuge near the fishing village of Galilee (Narragansett), Rhode Island[4] (Fig. 1). The majority of galls were produced on branch roots, most frequently at their tips (Fig. 2). Young galls were light yellow and translucent; old galls were dark brown. Mature galls measured 2 to 3 mm wide by 4 to 6 mm long. Nearly all galls on roots of American beachgrass were distinctly lemon-shaped, but some were elongated and recurved. Most of the galls examined contained small numbers of adults of D. radicicola, many young larvae, and many larvae encased in eggs (Fig. 3). This is a new host for D. radicicola and evidently its first reported occurrence in the United States.

FIGURE 2. (left) Galls on roots of American beachgrass incited by D. radicicola. Approximately three-fourths natural size.
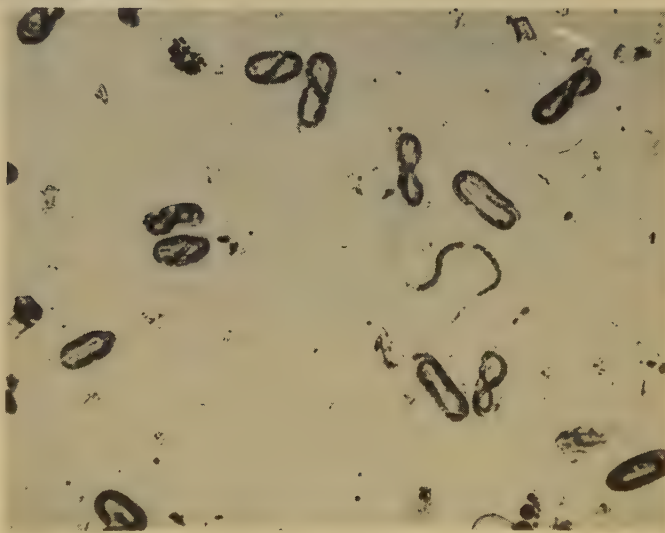
FIGURE 3. (right) Photomicrograph of larvae encased in eggs and young larvae of D. radicicola removed from root galls on American beachgrass. About X75.

        Subsequent sampling of the Galilee location showed the infection to be rather general throughout a 1-acre area of American beachgrass, approximately 100 yards from the high tide limit. More recent sampling of the beaches and coastal areas revealed the presence of root galls on this host at 12 locations extending from Middletown to Watch Hill, Rhode Island.
        Careful microscopic examinations of nematode specimens obtained from the new host in Rhode Island did not reveal the presence of any distinct and constant morphological characters different from those given in the description of D. radicicola by Goodey (3). The length of some of the apparently older mature females, however, approached 3.15 mm, which is given as the upper limit of length for D. radicicola. Length of stylet, position of vulva, and other

characters and measurements were well within the species description. Furthermore, comparisons of the Rhode Island specimens with D. radicicola obtained from Europe (through courtesy of Dr. M. Oostenbrink of the Netherlands and Dr. J. B. Goodey of England) did not show constant or significant morphological differences.

The widespread occurrence of a root-gall disease on American beachgrass and its incitant, D. radicicola, along approximately 20 miles of the southern shore of Rhode Island indicates this nematode species has been present in this country for a number of years. Surveys beyond its known distribution and surveys of other grass hosts in the State have yet to be made. Whether D. radicicola in the United States has the same host range as in other countries remains to be determined through host-range and other studies.

Since D. radicicola has been known for about 90 years and apparently causes galls on the roots of plants almost exclusively in the Gramineae, the common name "grass root-gall nematode" is proposed.

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CABBAGE VARIETIES IN RELATION TO TIPBURN

J. C. Walker, L. V. Edgington, and M. V. Nayudu

Cabbage tipburn is a nonparasitic malady of cabbage in which the margins of one to several inner head leaves become discolored, beginning at the hydathodes, as the plants approach maturity. The marginal tissue turns dark brown and desiccates to a thin papery consistency. Necrosis progresses toward the base of the leaf and not uncommonly eventually affects up to half of the leaf area. The disease is illustrated in U. S. Department of Agriculture, Agriculture Handbook 144[1]. It has been shown that the marginal head leaf tissue is exceedingly low in calcium[2]. While attempts to correct this disease by application of calcium salts as foliage sprays and as soil amendments have not been successful, it has been observed that varieties differ widely in their tendency toward development of this disease. The purpose of this communication is to make available our records on the prevalence of this disease in our variety test plots at Madison, Wisconsin, over the past decade.

The data presented in Table 1 are from 20 or more heads per variety per year. The varieties concerned are all yellows-resistant except Bonanza. They are all of the round-head type

Table 1. Incidence of tipburn in cabbage varieties, Madison, Wisconsin.

Variety	% plants showing tipburn in year indicated							
	1950	1951	1952	1953	1954	1959	1960	Average
Wisconsin Copenhagen	0	4	0	0	14	0	15	5
Bonanza	0	0	0	0	0	6	41	7
Resistant Detroit	8	8	0	33	35			17
Wis. Golden Acre	6	12	40	33	0			18
Marion Market	23	40	27	29	30			28
Globe	22	4	40		28	30	41	28
Badger Shipper						30	33	32
Greenback							33	33
Badger Market	21	16	31	46	26		91	39
Resistant Glory							56	56

and range from early to late midseason in maturity. They are arranged in the table on the basis of average percentage of plants showing tipburn. Tipburn varied somewhat from year to year in any given variety; Badger Market, Marion Market, and Globe were consistently high in incidence of tipburn, while Resistant Detroit and Wisconsin Golden Acre were high in some seasons and not in others. Badger Shipper, Greenback, and Resistant Glory, although tested in only one season, appear to be about equal to Globe in susceptibility. Wisconsin Copenhagen, an early maturing selection from Marion Market, has the lowest average incidence for the 7 years in which it was tested. Bonanza has an equally low incidence except for a very high incidence in 1960.

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VERTICILLIUM WILT OF POTATO IN NORTHERN INDIANA

Ralph J. Green, Jr., R. W. Samson, and Claude Fordyce[1]

In June 1960, a severe wilt and decline of potato was observed in a planting in Starke County, Indiana. The field had been recently cleared and was a light sandy soil. The only previous crop was corn grown in 1959 after the land was cleared.

The potato planting consisted of three varieties, Early Gem, Irish Cobbler, and Chippewa, and had been grown under supplemental sprinkler irrigation. Certified seed stocks were used in planting.

The symptoms observed included primary wilt, mottled chlorosis and premature death of the affected hills (Fig. 1). Vascular discoloration was present in most of the plants examined, especially in the lower stem. Disease incidence was scattered throughout the planting but the intensity of disease development varied with the variety. Symptoms were most prevalent in the Irish Cobbler variety (10 to 15%); Early Gem showed less than 5% and Chippewa only a trace. There was considerable black leg disease, caused by Erwinia atroseptica (van Hall) Jennison, in this planting but the symptoms of black leg are readily distinguished from the symptoms described above.

Verticillium albo-atrum Reinke & Berth. was consistently isolated from the potato stem sections. All isolates of this organism proved to be of the "dark mycelium" (dauermycelium) type. Robinson, Larson and Walker[2] indicate that this is the only type of the pathogen isolated from potato in Wisconsin and eastern Canada.
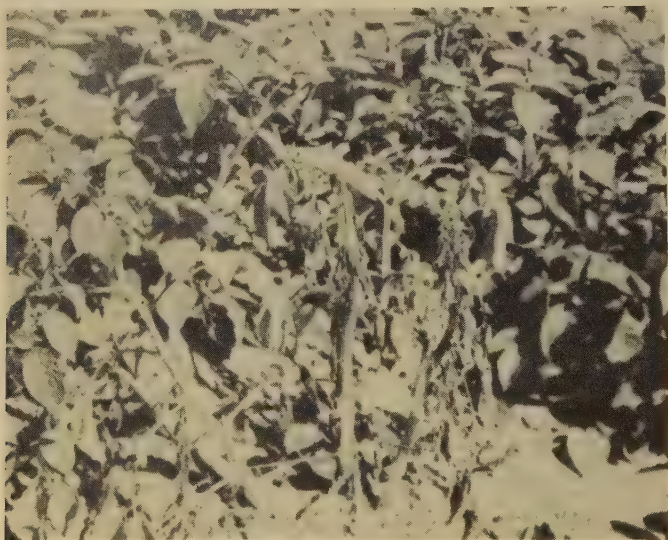
FIGURE 1. Symptoms of Verticillium wilt of potato in northern Indiana. Note the severe flagging and necrosis of the leaves and stems.

Verticillium wilt is an important disease problem on peppermint and spearmint in northern Indiana, but the strain of V. albo-atrum associated with this disease is highly host-specific and is of the microsclerotial type[3].

This constitutes the first report of Verticillium wilt disease of potato in the commercial production areas of northern Indiana. It is significant to note that the inoculum appears to have been introduced on seed stocks, since the field in which the disease was observed had not been previously cropped to potato and was well isolated from other plantings. Growers have been advised to treat cut seed potatoes with a fungicide to reduce surface inoculum of certified seed stocks and to follow a rigid crop rotation program.

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PROBLEMS OF PLANT DISEASE FORECASTING IN AN ARID CLIMATE

J. Palti[1]

Summary

The problems to be faced in forecasting plant disease outbreaks in arid climates differ in many essential respects from those encountered in temperate climates.

During the rainless season, pathogens requiring the presence of free moisture for their development have to depend on the presence of dew. The duration of the nightly period of dew, the temperature prevailing during that period, and probably also the intensity of dewfall, are the principal factors to be considered in forecasting in such cases. However, dew being a microclimatical factor, general disease forecasts dependent on dew are apt to be of questionable value.

During the rainy season, forecasts relating to diseases caused by pathogens requiring free moisture or high atmospheric humidity have to distinguish between the direct effects of dew and rain, and the effects of temperatures associated with dewy nights and rainy days. No data bearing on this problem are available at present.

The sources of inoculum for appearance of diseases of the moisture-loving type in arid climates are largely unknown. Elucidation of the way in which some such pathogens pass hot and dry summers is essential for the prediction of their appearance.

Pathogens tolerant of high and low humidity include a number of powdery mildews. The hosts of most of these fungi appear to become prone to infection, under field conditions, only after they have completed a certain part of their growing period although inoculum is in some cases permanently available. Forecasting outbreaks of such disease, both during the rainless and rainy seasons, involves determination of the period during which the host is not ordinarily prone to disease, and study of the factors which, after this period, advance incipient proneness to infection.

Pathogens restricted to low humidity, as exemplified by some further powdery mildews, evidently occur only in rainless seasons. In forecasting their outbreaks, we have to consider relative atmospheric humidity, preferably records for daytime periods only, as well as the above-mentioned factor of the host's proneness to disease.

INTRODUCTION

The practical importance of plant disease forecasting has been increasingly realized during the past years. Schemes for the prediction of plant disease outbreaks are now in operation, or in the process of being worked out, in a considerable number of countries. Miller and O'Brien (4) recently reviewed this work. Their survey shows that the schemes now operative cover chiefly downy mildews and allied diseases, some cereal rusts, and apple and pear scab. Most of these diseases are associated with temperate climates and conditions of high atmospheric moisture and precipitation; in their prediction, rainfall figures prominently as a macroclimatic criterion easy to measure.

In arid countries the pathogen flora is composed of species dependent on high moisture for one or more phases of their development, of species tolerant of both high and low humidities, and of species restricted to low humidities. Rainfall is lacking entirely for many consecutive months and temperatures during the dry season reach extreme values. Under these conditions attempts at disease prediction must be preceded by determination of suitable criteria essentially different in some respects from those employed in temperature zones. Here will be discussed some problems encountered in the quest for such criteria in Israel, (a) under the general headings of humidity, temperature, host-parasite relationship, and availability of inoculum, and (b) in their more specific application to the prediction of diseases of various ecological types during the rainless and the rainy seasons.

BACKGROUND OF PLANT DISEASE OCCURRENCE IN ARID CLIMATES

Humidity: Reichert (9) has stressed the importance of low humidity as the factor restricting development of pathogens of tropical origin, such as <u>Pseudomonas solanacearum</u>, <u>Sphace-</u>

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[1]Head, Plant Protection Section, Extension Administration, Israel Ministry of Agriculture.

loma fawcettii, and Phytomonas citri, in arid countries. Of equal practical importance is the fact that the low relative humidities obtaining in these countries over many months of the year during the hours of daytime limit infection processes of many pathogens of temperate origin to the hours of the night; this is exemplified by Plasmopara viticola and Phytophthora infestans. At the other end of the humidity scale, some of the xerophytic powdery mildews found in arid countries are undoubtedly limited by higher atmospheric humidities occurring during some seasons of the year.

In arid zones, the moisture requisite for development of many pathogens is supplied by dew, rain, and irrigation. Dew appears to be the most important because it is often available for periods of many consecutive hours and does not wash off spores. Both rain and irrigation may temporarily restrict development of some diseases by washing off the spores, but will eventually favor development of pathogens with affinities for high humidities by 1) extending periods of humidity beyond the nightly dew period, 2) providing humidity in daytime when temperatures are higher and facilitate more rapid pathogen growth, and 3) frequently increasing dewfall.

No literature detailing effects of irrigation on leaf disease development has been found. Observations in Israel indicate that overhead irrigation, much more than furrow irrigation, favors development of important leaf and fruit pathogens such as Phytophthora infestans and Pseudoperonospora cubensis. The effect of irrigation may certainly be expected to vary at different seasons; thus, after a few hours of irrigation on a summer day with low relative humidity, moisture on the leaves will dry up so rapidly that pathogens may have little chance to develop. The same irrigation on a winter day with higher relative humidity may result in extensive persistence of moisture on the leaves and may decisively influence disease development. The frequency of irrigation is of obvious importance, and so is the time chosen for its application. Irrigation towards evening or in the morning on a crop moistened by dew during the night may extend the period of uninterrupted moisture just long enough to permit the pathogen to penetrate; while irrigation during the night, when the plants are moist anyway, may have no effect. The problem of mode, frequency, and timing of irrigation, as related to plant disease outbreak, is now under investigation in the newly settled desert regions of Israel.

To summarize the humidity factors affecting disease development in arid climates, dew is of primary importance at most seasons. During the rainy season its effect is combined with that of rain, and during the rainless season its effect on irrigated crops may be greatly modified by irrigation. Dew itself is essentially a microclimatical phenomenon influenced by topography, wind, shade, and many other factors. The effect of irrigation depends largely on its mode, frequency, or timing. Under these conditions prediction of the appearance of high moisture pathogens cannot, in many cases, be expected to be of general regional value.

Temperature: The high temperatures obtaining in summer are certainly restrictive of the development of fungi originating from cooler climates, as pointed out by Reichert (9) with regard to Tilletia tritici, Sclerotinia sclerotiorum, and Phytophthora infestans. On the other hand, cool winter temperatures restrict fungi such as Sclerotium rolfsii and S. bataticola, as well as Pseudoperonospora cubensis. Temperature relations are especially important as forecasting criteria for fungi tolerant of very wide humidity ranges, such as many powdery mildews.

The temperature level is of equal importance in its effect on disease proneness of the host. This, under arid conditions, is particularly evident with regard to powdery mildews and Alternaria diseases which attack the host as it ages and may appear much sooner under warm than under cooler conditions.

Wind: The influence of winds on plant disease development in arid regions is pronounced. Of special importance is their effect during the rainless season on the intensity and duration of nightly dewfall, when the latter plays a decisive role in disease occurrence. Thus we have observed that in that part of Israel which lies between the sea and the Carmel range, Plasmopara viticola, Phytophthora infestans, and allied fungi occur much more rarely than in all other parts of the coastal plain. We incline to ascribe this difference to the drying effect of the down-draughts on the Carmel slopes.

Another effect of wind on crops grown in semi-desert regions has recently been studied by Rotem (11). He found that sandstorms, by injuring the foliage, greatly increase liability of potatoes and tomatoes to losses from Alternaria solani.

Host-Parasite Relationships: Dry and hot conditions preclude the development over many months of the year of many of the most virulent and destructive pathogens, such as Phytophthora infestans on Solanaceae, Peronospora destructor on onion, Alternaria dauci on carrots. In their absence, parasites of lesser virulence are increasingly in evidence; among these

the most important belong to the powdery mildew and the Alternaria groups. The powdery mildews as a group are characterized, according to Yarwood (13), by compatible association with their hosts, relatively slow increase during the season, and infrequent killing of the host.

With weaker parasites of this type, the reaction of the host when exposed to attack is of far greater significance than in the case of highly virulent pathogens capable of overcoming the defense reaction of their hosts whenever environmental conditions are favorable. Many powdery mildews, and a number of Alternaria fungi, infect their hosts much more readily during the later stages of crop growth and are often entirely absent during the earlier stages. Blumer (1) stated that the powdery mildews, by contrast with the downy mildews, may be considered a disease of advanced age (Alterskrankheit). Moreover, host reaction may well be influenced by growing conditions; in countries in which summer crops are extensively irrigated, great importance attaches to Yarwood's (12) findings that many powdery mildews develop on their hosts more profusely when these are grown under conditions of low soil moisture.

It is thus evident that host-parasite relationships as well as climatic conditions have to be taken into consideration in the prediction of some of the diseases most widespread in arid countries.

Inoculum: Most highly virulent leaf pathogens of the moisture-loving group, including downy mildews and rusts, are sharply limited in their choice of hosts and their season of appearance. Thus, in Israel, Pseudoperonospora cubensis is limited to cucumbers and melons, and is found in some years from May to November, in other years only from July onwards. The mode in which most of these pathogens pass the season unfavorable for their development is not known. This seriously hampers efforts to predict their seasonal appearance.

Of the more weakly parasitic leaf fungi common in arid countries, many species of powdery mildews and some species of Alternaria have much wider host ranges and appear at practically all seasons of the year. Thus Rayss (7, 8), in her numerous contributions to the fungus flora of Israel, has described the carrot mildew, Erysiphe umbelliferarum, on 13 species of wild plants, including common weeds, and the tobacco mildew (Erysiphe cichoracearum) on no less than 22 plants. In the absence of cross-inoculation tests, the role actually played by such wild plants in supplying inoculum for infection of crop plants remains uncertain. However, at least two crops severely affected by powdery mildew in Israel, namely carrots and beets, are grown all year round, and the same applies to solanaceous crops affected by species of Alternaria. In these cases inoculum may be considered to be permanently available.

SEASONAL PROBLEMS OF FORECASTING DISEASES CAUSED BY PATHOGENS OF VARIOUS ECOLOGICAL TYPES

Rainless Season

Pathogens Requiring Free Water on the Leaf: Dew has been shown by Duvdevani, Reichert and Palti (3) to supply the moisture required by the causal agent of downy mildew of cucurbits (Pseudoperonospora cubensis). That dew may likewise furnish adequate moisture for development of Phytophthora infestans is indicated, under Israel conditions, by occasional autumn outbreaks of potato late blight some weeks before the rainy season begins.

Where dew is thus the principal or only source of moisture on the leaf, the data likely to affect disease outbreak are (a) dew intensity, and (b) the duration of the nightly period during which dew is present on the leaf. Little is known about the effects of various dew intensities on disease development. However, the duration of the nightly dew period is obviously of critical importance because it may decide whether or not the pathogen manages to complete the infection process during the night. This is of particular significance where, as is often the case, the dewy night is followed by hot and dry hours of the day when infection hyphae that have not completed their penetration are liable to perish.

Here an important part is also played by temperature. As infection is limited to the hours of dew, the temperature level at any other time of the day becomes largely irrelevant unless it reaches values so extreme as to affect ungerminated spores. Therefore, temperature measurement during the hours of dew alone must be concentrated upon.

The interplay of the temperature level during the hours of dew and of the length of the nightly dew period has been studied by Duvdevani and his collaborators (3). It was found that downy mildew of cucurbits, which develops optimally around 20° C, failed to develop in June, when nights had 10-hour periods of dew only, in nights with minima of 16°, and appeared only when minima rose to 18° to 19°. However in the longer September nights, with 12-hour periods of dew, infection readily occurred after nights with 16° minima.

It may thus be concluded that, where inoculum is available, appearance of a disease with

ecological requirements similar to that of the downy mildew of cucurbits may be forecast on
the basis of duration of nightly dew period and temperature prevailing during that period. But
the dependence of dew formation on topography, shade, irrigation, and other factors makes
forecasts of general regional appearance unreliable.

Another problem in connection with this type of disease is that of the availability of inoculum. As mentioned before, Pseudoperonospora cubensis appears in Israel in some years from
May onwards, in other years as late as the end of July. In the years of late appearance,
periods suitable for development of the fungus, by all climatical criteria, occurred in May -
June and failure of the disease to develop was most likely due to absence of inoculum in the
early seasons of the years concerned. Elucidation of the sources of such inoculum and the
conditions leading to multiplication of primary inoculum to a level conducive to disease outbreaks are of obvious importance in prediction. It may then be possible to forecast the earliest time of appearance of a disease of this type in any part of the country in a given year, even
though its subsequent development under specific microclimatic conditions cannot be predicted.

The reaction of the host to a pathogen thriving under conditions of high humidity is, under
Israel conditions, of special interest in the case of Alternaria solani affecting potato and
tomato leaves. These crops, as they mature, become increasingly prone to infection by Alternaria. This fact, as well as the previously mentioned predisposing effect of sandstorms, is
definitely to be considered where prediction of this disease is to be attempted.

Pathogens Tolerant of High and Low Humidity: In this group we include a number of
powdery mildews, including those affecting in Israel cucurbits (Sphaerotheca fuliginea), carrots (Erysiphe umbelliferarum), sugar and fodder beet (Erysiphe communis), and peas (Erysiphe pisi). In the case of the cucurbit mildew it has been experimentally proved that free water
on the leaf is not required by the fungus (3). Field surveys have shown that the level of atmospheric humidity obtaining in Israel in summer has little effect on the occurrence of this mildew
(6). All the powdery mildews mentioned develop profusely during the rainless as well as the
rainy season.

If, then, we assume that atmospheric humidity is not ordinarily a limiting factor in the
development of these diseases, the question arises, what other factors may govern their appearance. The temperature relations of powdery mildews have been reviewed by Yarwood
and his collaborators (14). They quote 28° C as the optimum for Sphaerotheca fuliginea and
some sources of Erysiphe cichoracearum, and 23° to 25° as optimum and 32° as maximum for
mildews of the Erysiphe polygoni group to which our carrot mildew belongs. In the coastal
plain of Israel monthly mean temperatures during the rainless season range from 20° to 22° in
May and October to 25° to 27° in August-September; we may assume that here temperatures,
both in daytime and at night, rarely fall below or exceed levels suitable for development of the
mildews mentioned. However, delayed summer appearance of mildews on cucumbers and carrots in the Upper Jordan Valley, with mean August temperatures of 30° to 32° (Tiberias) may
well be due to excessively high temperature. This would agree with Yarwood's (13) statement
that the tolerance of powdery mildews to heat is usually lower than that of their hosts. It is
also in line with Yarwood's (13) observation that certain powdery mildews are more widespread
in the coastal area of California than in the interior valleys and that this may be due to the lower summer temperatures of the coastal areas. The role of high summer temperatures as a
factor limiting powdery mildew development thus requires consideration in prediction schemes
concerning these diseases.

As regards the availability of inoculum, we have mentioned that on carrots and on sugar
and fodder beet, powdery mildews have actually been recorded in Israel in every single month
of the year. An all-year round supply of inoculum from the host crop itself thus seems
assured; in addition, Rayss (8) has recorded Erysiphe communis in Israel on omnipresent
weeds such as Rapistrum rugosum, and E. umbelliferarum on wild carrot and many other
weeds. As regards mildews affecting host crops sown only during more limited seasons, the
cucurbit mildew, Sphaerotheca fuliginea, has been found by Rayss (private communication) on
the common weed Erigeron crispus. The actual importance of such weed hosts in causing
mildew outbreaks on crops cannot be assessed until cross-infection trials have been performed.

However, although in many arid regions during the rainless season neither humidity nor
temperature nor absence of inoculum seem to prevent development of the mildews mentioned,
it is a fact that the hosts concerned frequently fail to be affected for a considerable part of
their growing season. Thus, in Israel, under the above conditions, beets and carrots rarely
exhibit symptoms during the first half of their growth period, but are profusely affected at a
later stage.

A possible explanation for this phenomenon is that infection will only take place after the

host has reached a certain level of disease proneness. Our observations lead us to suspect that many hosts pass three consecutive phases of proneness to powdery mildew attack: (a) In the first phase the hosts are unlikely to be infected by their mildews, no matter how favorable environmental conditions are to the fungus. This may be followed (b) by a phase during which the host is ordinarily not prone to infection, but may be rendered more susceptible under special conditions, for example, at certain temperature levels or where soil moisture is deficient. The latter factor, as mentioned earlier, has been investigated by Yarwood (12) in relation to the powdery mildews of eight important hosts. This stage would then appear to be followed (c) by a phase in which the host is prone to mildew attack under all the conditions normally obtaining in the field.

Prediction of the appearance of this type of disease under the conditions prevailing during the rainless period thus involves 1) determination of the length of the phase during which each host is not ordinarily prone to the disease, and 2) investigation of the factors which, after this initial phase is completed, will render the host increasingly prone to disease.

Pathogens Limited to Low Humidity: This group is exemplified in Israel by the powdery mildew of potatoes, which in the absence of cleistothecia can only be referred to as Oidium erysiphoides Fries, by the Oidiopsis mildew of lucerne, and the same mildew on tomato (Oidiopsis taurica Tepper).

The availability of inoculum of these fungi at various seasons remains an open question. As regards the powdery mildew on potato, the species of causal fungus has not been identified and the extent to which inoculum may derive from other wild and cultivated hosts is uncertain.

The temperature relationships of the mildews in this group have not been adequately studied. However, there is reason to believe that during the rainless period temperatures do not fall below levels suitable for development of all three of the above mildews. Absence of Oidiopsis on lucerne and tomato at the height of the summer season in the Jordan Valley, and appearance of these diseases in that locality in autumn on host plants of comparable age, may well indicate that high temperatures limit the occurrence of these fungi, as in the case of the previously discussed powdery mildews.

It is, however, the level of atmospheric humidity which essentially limits appearance of the above mildews. A field study of the potato mildew has shown it to be a pronounced xerophyte (6). The same definitely applies to the lucerne mildew, and to a somewhat more limited extent to the tomato mildew.

Oidiopsis taurica is one of the fungi most commonly found in Israel, where it has been determined by Rayss (7, 8) on no less than 53 wild and cultivated hosts. That the species comprises various strains infecting different hosts has been indicated by Zwirn (15) and Ciccarone (2). On the other hand, Nour (5) has shown that inoculum from certain weeds may infect cultivated hosts. It must be concluded that the extent to which inoculum for infection of tomato and lucerne may be derived from wild plants infected with Oidiopsis cannot be properly assessed until the necessary cross-infection trials are carried out.

In dealing with mildews of this type, means of relative atmospheric humidity for the hours of the day alone, or daytime minima, appear preferable to means of such humidity for the whole 24-hour period, for the purpose of linking the appearance of the mildews to certain levels of humidity.

In addition to the limitations imposed by the low humidity requirements of these mildews, their appearance is limited by the fact that at the younger stages of growth their hosts do not seem prone to infection, just as is the case with the mildews of the previously described group. These changes in disease proneness are pronounced on potatoes and lucerne, somewhat less so on tomatoes.

Prediction of the appearance of diseases of this group must thus be based on considerations of (a) levels of relative atmospheric humidity conducive to disease appearance or precluding such appearance, and (b) determination of the period during which hosts are not prone to infection and of the factors which will thereafter render them increasingly prone to the disease.

Rainy Season

Pathogens Requiring Free Water on the Leaf or High Atmospheric Humidity: During the rainy season pathogens of this group meet the necessary moisture 1) on rainless days mainly during the night (dew), and 2) on rainy days both during the night and during some or all hours of the day. The rainy days obviously present the pathogens with the best chances for development because they provide long and continuous periods of moisture, whereas the moisture period in dewy nights is strictly limited. No less important is the fact that the nights during this season are relatively cold, and the low temperature may prevent completion of the infec-

tion process during the limited hours of dew. But in daytime, even if the day is rainy, the temperature rises and becomes more favorable to rapid infection by most of the pathogens of economic importance. Rainy days thus enable pathogens to develop continuously for longish periods during part of which temperatures are highly favorable.

Rain is a macroclimatical factor readily and widely used for disease forecasting, while dew, as already mentioned, is largely a microclimatical factor not easily used for general predictions. Attempts at disease forecasting under these conditions are thus faced with the problem how to distinguish between the effects of dew and of rain on pathogens with high-moisture affinities, such as Erysiphe graminis DC., Phytophthora infestans (Mont.) d By. and Peronospora destructor.

Most of the diseases favored by humidity appear during the rainy season after a period of total absence during the dry and rainless summer season. Thus the downy mildew of onions (Peronospora destructor), after affecting the spring crop (up to June), is absent from all districts of Israel until the following January or February; the disease thus fails to affect onions in autumn and, in spite of favorable temperatures, appears only 2 to 3 months after the onset of rains. Similarly, the rust of broad beans (Uromyces fabae) will not appear on autumn-sown crops until the rainy season is well-advanced. In such cases it would seem that absence of disease during the earlier part of the rainy season is largely due to lack of inoculum. Much more will have to be known about the mode of oversummering of such pathogens before their attack can be predicted.

With some other fungi affecting crops during the rainy season, notably the Alternaria group, the availability of inoculum does not appear to be a limiting factor. But certain members of this group, as mentioned in an earlier section, are largely restricted to maturing crops, and their incidence can often be related to sandstorms.

The temperature level during the rainy period is of obvious importance for the appearance of many pathogens. Reichert and Palti (10) have studied the factors causing Uromyces fabae to affect broad beans in Israel in some years as early as January, in others as late as mid-March. They found the disease to appear earlier in years with January mean temperatures of 12.5° to 14°C, but to appear later in years where this figure was about 10°.

Pathogens Tolerant of High and Low Humidities: The conditions favoring appearance of diseases caused by pathogens in this group, notably some powdery mildews, have been discussed in some detail. Here only the special effects of the rainy season on these diseases will be referred to.

Although the fungi concerned may develop over a wide range of moisture conditions, some of them cause earlier and more serious outbreaks under conditions of plentiful rain. This may be due to stimulation of the pathogen or to increased disease proneness of the host under such conditions. For example, Erysiphe communis in Israel affects autumn sown fodder beet at an earlier phase of growth and with greater virulence in years with high amounts of rainfall in the months of November to December than in years in which these months are relatively dry.

More important for this group as a whole are the temperature levels associated with rainy and rainless days. As the latter are often warmer, the effect of rainless spells on disease appearance may sometimes be attributed to higher temperatures rather than to absence of rain or low atmospheric humidities. Here again, temperature affects the pathogen as well as disease proneness of the host. Thus, diseases such as powdery mildew of carrots affect the crop at an earlier phase in years with early winter months of scant rainfall and higher temperatures than after rainy and colder months.

But for infection to succeed, the host must have passed that phase of growth in which it seems incapable of being rendered disease prone under ordinary conditions. This phase may in many cases be quite extensive under the low-temperature conditions of the rainy season, and may prevent disease appearance well into the second half of the growing period of the host crop.

Prediction of the outbreak of diseases of this type during the rainy season thus raises approximately the same problems as during the rainless season, that is, determination of the early period during which hosts are not prone to disease and study of the environmental factors which tend to advance the stage of incipient proneness to disease.

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PLANT PROTECTION SECTION, EXTENSION ADMINISTRATION, ISRAEL MINISTRY OF AGRICULTURE

FOMES ANNOSUS ROOT-ROT IN SLASH PINE PLANTATIONS OF THE EASTERN GULF COAST STATES

Chas. H. Driver and T. R. Dell

Abstract

A survey during October 1960 showed that evidence of the disease of annosus root-rot was prevalent in various degrees in thinned slash pine plantations of the coastal plain of Georgia, Florida, Alabama and Mississippi.

A preliminary survey during October 1960 for evidence of the occurrence of annosus root-rot, Fomes annosus, in slash pine plantations was conducted on the lands of International Paper Company within the Coastal Plain of Georgia, Florida, Alabama, and Mississippi.

Results of observations in plantations thinned within the past 2 to 5 years showed the presence of symptoms of the disease under the following conditions at the locations indicated on the map (Fig. 1).

LEGEND: Locations of infestation sites by county and State.

1. Decatur Co., Ga.   5. Lee Co., Ala.
2. Jackson Co., Fla   6. Covington Co., Ala.
3. Calhoun Co., Fla.   7. Baldwin Co., Ala.
4. Houston Co., Ala.   8. Jackson Co., Miss.
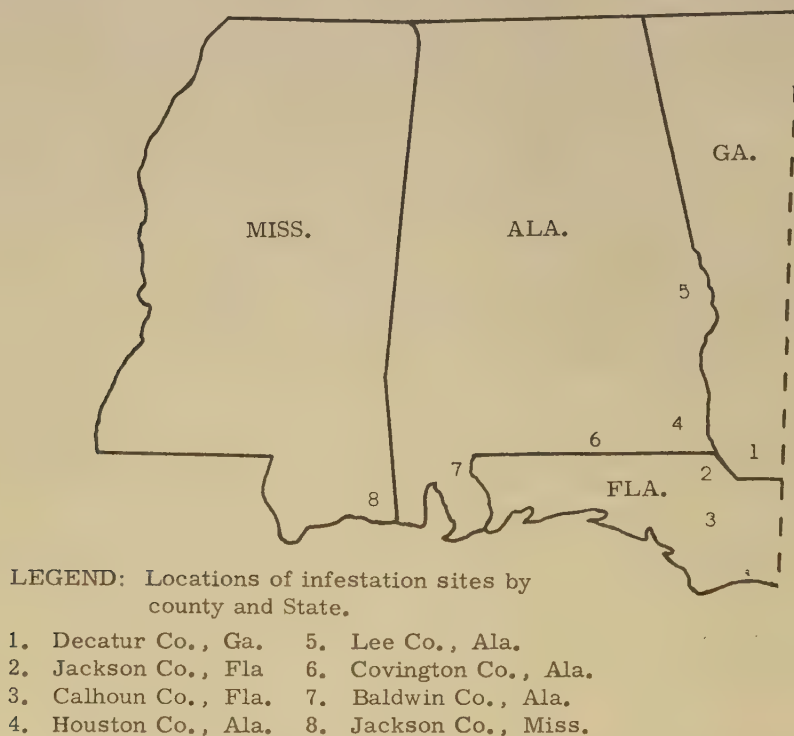
FIGURE 1. Occurrence of annosus root-rot in old field, slash pine, plantations of the Eastern Gulf Coast States.

1. Decatur County, Georgia: Several plantations in this area ranging in age from 12 to 22 years were observed exhibiting various symptoms of the disease[1]. All of these plantations had been established on abandoned agricultural fields and were exhibiting the acceptable growth rate of at least one cord per acre per year. The stands were thinned in various degrees ranging in volumes removed from 1 to 4 cords per acre. The thinnings occurred within the period of 2 to 5 years from the date of this observation. Damage appeared to be in proportion to the time since the first thinning. In this respect, stands thinned within the past 2 years exhibited

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[1] Dr. W. A. Campbell of the Southeastern Forest Experiment Station of the U.S. Forest Service confirmed many of these diagnoses.

smaller volumes in dead trees when compared with damage occurring in the stands thinned 5
years ago. An example of severe damage was observed in a plantation exhibiting the follow-
ing characteristics:

A 22-year-old slash pine plantation established on an abandoned agricultural field
had been thinned very lightly 5 years ago. The total volume of standing timber in the
stand is about 30 cords per acre. Within the past 5 years mortality in this stand
amounted to approximately 12 cords per acre, with an additional volume of 7 cords
per acre in presently living trees exhibiting symptoms of the disease.

2. Jackson County, Florida: A thrifty appearing 22-year-old plantation established on an
abandoned agricultural field exhibited positive symptoms of the disease. This stand was
thinned 4 years ago and several pockets of dead trees were observed on the exposed side near-
est the road. A skyward view of one such pocket is demonstrated in Figure 2.

FIGURE 2. A skyward view of typical
mortality thought to be induced by annosus
root-rot on slash pine.

3. Calhoun County, Florida: A 22-year-old plantation was observed expressing only
limited evidence of the disease. The stand was established on an abandoned agricultural field
and it had been thinned twice, 1 and 5 years ago. A few single standing dead trees in this
stand were observed bearing fruiting bodies of Fomes annosus (Fr.) Cke.

4. Houston County, Alabama: Observations on a thrifty appearing 23-year-old plantation
established on an abandoned agricultural field at an original spacing of 10 x 20 feet showed the
following condition. The stand had been lightly thinned 5 years ago. Two standing dead trees
were observed which appeared to have been killed by annosus root-rot; however, fruiting
bodies of the pathogen were not observed at or near the bases of the trees. Roots collected
from these trees were found to contain the imperfect stage of F. annosus when incubated at 70° F
for 7 days.

5. Lee County, Alabama: Examination of a 28-year-old plantation that had been thinned
twice, the most recent approximately 4 years ago, showed a stand that exhibited typical symp-
toms of the disease. In this case light damage only was observed.

6. Covington County, Alabama: One 19-year-old plantation exhibiting low vigor and rough
form contained scattered individual standing dead trees bearing fruiting bodies of F. annosus.
It had previously been thinned 4 years ago.

Within the area a second plantation 15 years of age, appearing to be in a thrifty condition,
was found to exhibit a high degree of infection. Numerous standing dead trees, singles and in
groups, were scattered throughout the 19 acres of the stand. It had previously been thinned 5
years ago and was in the process of being thinned a second time at this observation. The plan-
tation was established on an abandoned agricultural field.

7. Baldwin County, Alabama: A 20-year-old plantation established on an abandoned agri-
cultural field was found to be exhibiting positive symptoms of the disease. The cultural history
of the stand shows that 6 years ago considerable storm damage occurred in the form of wind
throw and, as a result, salvage cutting was conducted. Since that time the stand was thinned 2
years ago. Trees dying by ones and twos were observed throughout the plantation. This stand

had been control burned three times in the past, therefore, only light duff was apparent. Fruiting bodies of F. annosus, however, were observed on or near many of the dead and dying trees.

8. Jackson County, Mississippi: In a 28-year-old plantation which had been thinned twice, 7 and 5 years ago, the fungus was found fruiting on two dead snags. It was determined, therefore, that only a light infection existed. In this same respect, a cursory examination of a 34-year-old plantation in the same locality that had been thinned five times showed no obvious symptoms of infection. Both stands exhibited a relatively low stem density.

Typical fruiting bodies of Fomes annosus were collected in each of the infected stands except the Houston County, Alabama plantation. On microscopic examination of all the material collected, no evidence was found to indicate that the fruiting bodies were abundant producers of basidiospores.

These observations appear to indicate that the disease of annosus root-rot in slash pine plantations, within the precinct of this survey, can be described as widespread. In addition, this disease appears to be associated with various degrees of damage following thinning operations in slash pine plantations of this area.

SOUTHLANDS EXPERIMENT FOREST, INTERNATIONAL PAPER COMPANY,
BAINBRIDGE, GEORGIA

APICAL NECROSIS IN ORNAMENTAL FOLIAGE PLANTS
CAUSED BY RAPID TEMPERATURE CHANGES[1]

S. O. Graham[2]

The wholesale production of foliage plants in Washington State is dependent upon imports of cuttage or rooted cuttings from various localities in the southern United States or from tropical plantations outside the United States that specialize in this industry. Frequently, rooted cuttings of Monstera deliciosa (Philodendron pertusum) are brought into the State by air freight from these sources. Upon arrival the cuttings are excellent in appearance. However, shortly after potting frequently the first new leaf of numerous plants is blackened when it emerges. The economical implications when this happens are obvious.

Repeated isolations failed to disclose any pathogen associated with this condition. Of several possible causes, those involving environmental fluctuations, particularly fluctuations in temperature during air transit, seemed worthy of investigation. Hence, studies were conducted in which temperature was manipulated. Plants of Monstera deliciosa, Ficus elastica, Philodendron hastatum, Dracaena deremensis var. warneckei, Dracaena fragrans var. massangeana, and Dieffenbachia picta which had been growing at 78° F were divided into duplicate groups. One group was placed in an atmosphere held at 60°, and the other group at 95°. Plants were cultured at these two temperature levels until a new leaf was produced. There was no evidence of blackening.

Two-thirds of each group were then exposed to the opposite temperature. After 48 hours half of these were returned to the original temperature. All plants were grown until they produced a new terminal leaf. Table 1 indicates the conditions which brought about terminal necrosis.

Table 1. Apical necrosis in certain foliage plants as induced by temperature manipulations.

Host	Temperatures (°F)					
	60	95	60-95	95-60	60-95-60	95-60-95
Monstera deliciosa (Philodendron pertusum)	-	-	+	-	+	+
Philodendron hastatum	-	-	+	-	+	-
Ficus elastica	-	-	+	-	+	+
Dracaena fragrans var. massangeana	-	-	+	-	+	-
Dracaena deremensis var. warneckei	-	-	-	-	-	-
Dieffenbachia picta	-	-	-	-	-	-

The results of this study show that a rapid rise of 35 degrees can be a critical factor in bringing about apical necrosis in foliage plants. A rapid, similar drop in temperature alone apparently does not bring about apical necrosis. Low temperatures followed by a rapid rise initiated apical necrosis in Monstera deliciosa, Ficus elastica, Philodendron hastatum and Dracaena fragrans var. massangeana. This was true even if the duration of increased temperature was only 48 hours. However, only Monstera deliciosa and Ficus elastica were sensitive to a relatively short duration of low temperature followed by a rapid change back to a high temperature.

It is suggested, therefore, that sudden fluctuations from low to high temperature should be prevented during shipment of susceptible cuttage by packaging in insulated containers. If the shipment is delayed in transit, exposure to high temperatures should be avoided. Cuttage received by the wholesaler or grower should slowly be brought to the normal culturing temperatures of his greenhouses.

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IMPROVING GROWTH OF FRUIT TREES BY TREATMENT WITH NEMATOCIDES AND FUNGICIDES AT TIME OF PLANTING

P. M. Miller

Summary

Inclusion of a fungicide, either pentachloronitrobenzene or oxine sulfate, or a nematocide, 1,2-dibromo-3-chloropropane, at planting increased shoot growth of apple trees up to 40%. Control of root rot fungi produced most of the extra growth, for addition of nematodes to pasteurized soil reduced growth only slightly and not all nematocides increased growth.

The roots formed immediately after transplanting are most important to new fruit trees. These roots form the origin of much of the secondary root system and preventing injury to them by root-rotting fungi and parasitic nematodes is necessary to obtain optimum secondary root development. Earlier work on root rot of strawberries (3) has shown that fungicide-nematocide combinations give good control of root pests. This work suggested that addition of a small amount of a fungicide or nematocide or both to the soil around a fruit tree at transplanting time was a simple method for preventing injury to primary roots and consequently for increasing growth. To test this hypothesis, two fungicides and three nematocides, separately and in one combination, were put in the soil around young apple trees at planting time.

MATERIALS AND METHODS

Four 2-year-old Monroe apple trees on Malling II rootstock were used for each treatment. Each tree was planted in a metal can which held 45 pounds of a fine sandy loam on which apple trees had been grown in 1956. Use of soil in which apples had grown previously was considered desirable as new orchards are often planted on old orchard sites. The inside of each can had been coated previously with a non-toxic water emulsifiable asphalt paint to prevent rusting.

The fungicides used were 8-hydroxyquinoline sulfate (OQS or oxine sulfate) and 20% pentachloronitrobenzene (PCNB) (Terraclor). Nematocides used were 50% emulsifiable concentrate of 1,2-dibromo-3-chloropropane (DBCP) (Nemagon EC-2), 10% granular 3,4-dichlorotetrahydrothiophene 1,1-dioxide (PRD), and 75% emulsifiable concentrate of O-2,4-dichlorophenyl O-O-diethyl phosphorothioate (VC-13). The amount of the insoluble materials needed for each can (PRD--1.5, 4.5 and 7.5 g; PCNB--4.5 g) was mixed with the soil just prior to placing around the roots. The soluble or emulsifiable materials (oxine sulfate--12 g; DBCP--0.3 and 0.6 ml; VC-13--2.5 and 7.5 ml) were mixed with 4 liters of water and poured around the trees immediately after planting. Oxine sulfate (12 g) and PRD (1.5 g) were mixed as a combination fungicide-nematocide treatment. An equal volume of water was poured around all other trees not receiving water as part of the treatment.

Other tests were made simultaneously to determine the nature and seriousness of the root-deteriorating microorganisms. To estimate the injurious effect of these microorganisms, a lot of soil was pasteurized at 82° C for 45 minutes. To evaluate nematode injury, nematodes were extracted from four cans of soil by the centrifugal sugar flotation method (1, 4), surface-sterilized by overnight soaking in 100 ppm of streptomycin sulfate, rinsed and then added to four cans of pasteurized soil. The nematode population was 20-25 Pratylenchus penetrans and P. pratensis, 3-5 Xiphinema americanum, 10-15 Paratylenchus sp. and an occasional Tylenchorhynchus sp. and Rotylenchus sp. per pint of soil. In addition, four cans of sterilized soil without nematodes were planted.

After planting on May 17, 1957, the cans and trees were placed on top of the ground in a randomized block design. A salt hay mulch 6-cm thick was placed around each tree to reduce water loss. Fertilizer, water and foliar applications of pesticides for control of insects and diseases were added as necessary during the two growing seasons of the experiment.

In January 1959, after two seasons of growth, the trees were removed from the cans and the roots were washed free of soil. The root system was rated on a scale from 1 to 10 for the amount of roots (10 = very large root system) and again for the general health of the roots (10 = roots white with little browning or root rot). The root index for each tree is the sum of the two ratings with a maximum of 20. The influence of the soil treatments on aerial development was determined by measuring all shoot growth occurring after planting and also the cross-

sectional area of the trunk 7 cm above the soil line was determined at the end of the experiment.

The nematode population around each tree was determined by extracting them from 100 g of soil by a modification of the centrifugal-flotation method. The 100-g soil sample in a 5-ounce paper cup is well moistened and washed with a fine stream of water through a screen, whose mesh openings are of approximately 0.5 cm, into a 500-ml paper cup. The stream of water breaks apart soil clumps and root masses while washing the soil through the screen and also keeps the nematodes in suspension. After the cup is filled the mixture is allowed to settle for 1 minute. The supernatant, containing fine soil particles and nematodes, is poured into another cup and allowed to stand overnight; and the sediment in the first cup is discarded. In the second cup the sediment will contain the fine soil particles and the nematodes. The supernatant is discarded after being carefully decanted and two or three volumes of sugar solution are thoroughly mixed with sediment. This mixture is then centrifuged for 1 minute at 1000 G. The supernatant is poured on a 325 mesh screen, rinsed with water, washed into a 5-ounce paper cup and counted. If necessary, the cups can be stored in a plastic bag or moist chamber at 2° C until counted.

RESULTS

Results are summarized in Table 1. Treatment with oxine sulfate, PCNB, PRD at 4.5 g per tree, DBCP at 0.6 ml per tree and soil pasteurization significantly increased shoot growth and generally increased stem size and improved root condition. VC-13 and other amounts of PRD were ineffective in increasing growth. The combination of PRD with oxine sulfate was no better than oxine alone. Addition of surface-sterilized nematodes to pasteurized soil reduced shoot growth only slightly below that on trees grown in pasteurized soil. Nematode populations at the ends of the experiment were very low, usually less than 3 to 5 P. penetrans or P. pratensis and only an occasional specimen of other parasitic nematodes. Many samples had no parasitic nematodes of any type.

Table 1. Growth of young apple trees treated with a nematocide or fungicide at time of planting.

Treatment	Amount added 4 gallons of soil	Total shoot growth in two seasons[a] (centimeters)	Cross-sectional area of stem[a] (sq. centimeters)	Root index 20 = max.[b]
Oxine sulfate	12.0 g	295	2.68	15.0
Terraclor	4.5 g	312	2.41	14.8
PRD	1.5 g	175	1.90	11.8
PRD	4.5 g	270	2.15	13.0
PRD	7.5 g	103	1.90	8.8
Oxine sulfate + PRD	12.0 g 1.5 g	298	2.58	14.0
VC-13	2.5 ml	200	1.83	11.5
VC-13	7.5 ml	220	1.90	11.5
Nemagon	.3 ml	235	2.07	14.8
Nemagon	.6 ml	323	2.24	15.0
Pasteurized soil	--	287	2.32	15.3
Pasteurized soil + nematodes	--	268	2.24	14.5
Unsterilized soil	--	229	1.99	12.8
LSD .05		22		

[a]Average of four trees per treatment.
[b]Root index is sum of two ratings, amount of roots produced (10 = maximum) + root vigor (10 = maximum with very white roots and no root rot). 10 + 10 = maximum.

DISCUSSION

Increases in shoot growth up to 40% in the 2 years after planting has been obtained by a simple treatment at time of planting. Control of root-rotting fungi is indicated as producing most of the extra growth. Both fungicides increased growth and only part of the nematocidal treatments increased growth. Addition of surface-sterilized nematodes did not greatly reduce

growth or root vigor and nematode populations were low at the end of the test. Neither oxine sulfate nor PCNB has shown any nematocidal properties and both are fairly specific in controlling Rhizoctonia solani among root-rotting fungi. DBCP has shown ability to inhibit this fungus in soil and increases in growth following its use in this test are probably due to fungicidal rather than to nematocidal control. However, in two other areas DBCP applied around newly-planted trees increased shoot growth or cross-sectional area of the stem up to 40%. In one of these areas parasitic nematodes were present in rather large numbers, and here increased growth may have been due to control of both fungi and nematodes. Control of both fungi and nematodes by chemicals is not unusual and thus part of the increased growth produced by 4.5 g of PRD per tree might be due to control of fungi rather than of nematodes.

McKeen and Mountain (2) found P. penetrans increased injury by Verticillium albo-atrum Reinke & Berth. on eggplants (Solanum melongena) but P. penetrans alone had little effect. Results in this test suggest that nematode injury must be accompanied by infection with R. solani to significantly affect growth of the apple trees. If the R. solani is controlled, the nematodes are of little importance.

There is a possibility that nematode injury was obscured by several factors. One factor is that nematodes may have produced injury at the start of the experiment but conditions in the cans were unfavorable for maintenance of high populations over the duration of the test. Another factor is that the non-volatile VC-13 and PRD at 1.5 g per tree were not distributed throughout the soil in time to prevent most of the critical injury, whereas the volatile DBCP permeated the soil and prevented nematode injury. Despite these possibilities, however, it appears that most of the extra shoot growth obtained in this test was due to control of root-rotting fungi.

The relative importance of root-rot fungi and nematodes may differ among planting sites, but it is inexpensive and simple to treat around new trees with both nematocides and fungicides. Both pests are controlled with little extra cost and effort and considerable gains in tree growth may result.

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SYMPTOMS AND TRANSMISSION OF A "STAR CRACKING" TYPE DISEASE OF APPLE IN WASHINGTON[1]

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In 1954 our attention was called to a diseased condition of several Golden Delicious apple trees in an orchard near Wapato, Washington. The trees bore malformed fruit with symptoms similar to those later described for the star cracking virus disorder (2, 3). Shortly after the calyx stage, the fruits on diseased trees begin to show russeted areas. In very severe cases the developing fruit is restricted in growth, resulting in dwarfing and malformation. Some of the apples at harvest time are no larger than walnuts. Less severely affected fruits are nearly normal in size but show cracks in the center of the russeted areas giving the impression of "star cracking" (Fig. 1).
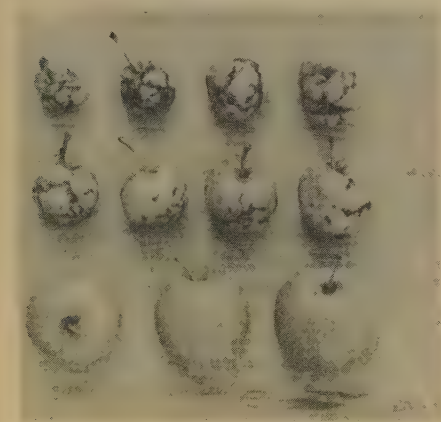

FIGURE 1. A "star cracking" type fruit symptom on Golden Delicious. The upper two rows show severely deformed and cracked fruit. The lower row shows normal fruit. August, 1960.

So far as can be determined there are no associated leaf symptoms. During the process of establishing transmission tests a spot necrosis of the inner bark and a prominent furrowing and ridging of the wood of the branches on affected trees was observed. One tree was later indexed on several crab apple index plants and found to be carrying the stem pitting virus (1), but this virus so far as known does not cause fruit deformity. The affected trees were mature and had borne malformed fruits for many years but the condition had been believed by the grower to be due to spray and/or other environmental factors. Several of the severely affected trees have been removed. At the present time there are still a few diseased trees in the original orchard and two such trees of fruiting age have been found in a young planting in the same area.

In 1955 budwood from diseased trees was placed on young Jonathan and Starking trees in plots at Prosser, Washington[3]. Fruit produced on the growth from the inoculum buds has shown that the condition is perpetuated but there is no evidence of transmission.

In March 1957 budwood from Golden Delicious trees which had consistently borne normal fruit was grafted onto one of the diseased trees in the original orchard. During the summers of 1959 and 1960 these grafts produced fruit which had symptoms typical of those on fruit from the rest of the tree. Based on this inoculation test, it is assumed that a virus has been transmitted to the healthy grafts and the symptoms are similar to those described for star cracking.

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1957-1960 EVALUATION OF DBCP APPLICATION RATES, TIME OF APPLICATION, AND PHYTOTOXICITY ON SELECTED TRUCK CROPS IN SOUTH GEORGIA[1]

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Summary

Nematode control with in-the-row applications of 1,2-dibromo-3-chloropropane (DBCP), dichloropropene-dichloropropane mixture, and ethylene dibromide was compared during 1957, 1958, 1959, and 1960 on Tifton sandy loam in Georgia. Applications of 138 ml of technical DBCP per 1000 feet of row (0.50 gallon/acre with 38-inch row spacing) or with 174 ml per 1000 feet of row (0.50 gallon/acre with 48-inch row spacing) usually controlled root knot satisfactorily, but 69 ml per 1000 feet of row (0.50 gallon/acre with 38-inch row spacing) did not always do so. Phytotoxicity symptoms were observed on tomato transplants in 3 years' experiments and on a variety of crop plants in 1960 under conditions which apparently have to do with low volatility of DBCP. Phytotoxicity tended to be less for preplanting than for at-planting applications of DBCP.

Use of 1,2-dibromo-3-chloropropane (DBCP) on a number of common crop plants in south Georgia for control of root-knot, sting, and root-lesion nematodes has been reported previously (3, 4, 5, 6, 13). Similar investigations have been made in other areas of the country for a number of different crops (2, 8, 9, 11, 12). This chemical is now being used under a wide range of conditions for preplanting, postplanting, and at-planting soil treatments for a number of field, truck, fruit, and ornamental crops.

The purpose of this paper is to report experimental data on nematode control with in-the-row applications of DBCP and observations on phytotoxicity.

GENERAL PROCEDURES

Four experiments conducted during 1957-1960 at the Georgia Coastal Plain Experiment Station, Tifton, Georgia are reported in this paper. Each test was located in a different field, but in each case the soil type was a Tifton sandy loam with a field capacity of 8.4 to 8.6% soil mixture (oven dry). Nematocides were applied in the spring when soil moisture was at least 80% of field capacity, and soil temperature ranged from 50° to 60° F in the mornings and 60° to 70° in the afternoon.

Chemicals were applied as in-the-row applications with tractor-drawn equipment. All formulations were applied as liquids with constant gravity-flow applicators except for the 1960 test, in which DBCP was applied in granular form with a row-insecticide applicator. DBCP was compared with standard nematocides, ethylene dibromide (EDB) or 1,3-dichloropropene, 1,2-dichloropropane mixture (D-D).

The design of each experiment was amenable to statistical evaluation with randomized plots réplicated five to eight times. Cultural practices consistent with generally accepted procedures were followed for all test plants.

Severity of root-knot galling was determined by rating freshly dug roots by an index system as follows: 0, free of galling; 1, trace of galling; 2, light galling; 3, moderate galling; and 4, heavy galling. Soil counts were made by separation of nematodes from the soil by a modification of the Baermann funnel method described by Christie and Perry (1).

1957 DBCP DOSAGE TEST FOR CONTROL OF ROOT-KNOT NEMATODES

Three rates of DBCP[3] were applied in-the-row, 9 days before planting, for control of Meloidogyne incognita acrita Chitwood, 1949, on Burpee Giant Stringless Green beans, Stokes-cross No. 5 tomatoes, and Speckled Purple Hull cowpeas. Technical DBCP was diluted with Stoddard solvent and was applied at dosages equivalent to 0.25, 0.50, and 1.00 gallon/acre of

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technical DBCP for a row spacing of 38 inches[4]. It was applied approximately 10 inches below the soil surface and was listed on with disc-hiller plows.

Average yields and root-knot indices are given for the various soil treatments in Table 1. These data indicate that all application rates of DBCP gave excellent root-knot control but without significant differences between rates; however, control tended to increase as the dosage increased. Yields of tomatoes and cowpeas were significantly higher for the low dosage than for the controls and were lower for the highest and medium application rates, which indicates that DBCP may have been phytotoxic at the higher application rates.

Table 1. Effect of 1957 DBCP application rates on control of root knot and yields of tomatoes, cowpeas, and green beans. (means based on five replications)

Soil treatment	Application rate[a] (gallons/acre)	Tomatoes		Cowpeas		Beans	
		Mean root-knot index	Yield (tons/acre)	Mean root-knot index	Yield (tons/acre)	Mean root-knot index (0-4)	Yield (tons/acre)
DBCP	0.25	0.16*	10.1*	0.06*	8.5*	0.16*	0.99
DBCP	0.50	0.22*	9.6*	0.10*	8.4*	0.15	0.98
DBCP	1.00	0.00*	8.2	0.07*	7.4	0.08*	0.97
Unfumigated controls	none	1.41	7.2	1.01	6.1	1.67	0.88
L.S.D. .05		0.79	2.2	0.22	1.7	1.22	n.s.

[a]Application rate given as technical material, with row spacing of 38 inches.

1958 EVALUATION OF APPLICATION OF DBCP AT PLANTING TIME FOR CONTROL OF ROOT-KNOT NEMATODES

Two formulations of DBCP were tested for control of root-knot nematodes, M. incognita (Kofoid & White) Chitwood, 1949, on Rutger's tomatoes, Model cucumber, Early Summer Crookneck squash, Henderson Bush lima beans, Tendergreen beans, and Clemson Spineless okra. A 50% by volume emulsifiable concentrate of DBCP[3] was diluted with water and applied at 0.25, 0.50, and 0.75 gallon/acre equivalent of technical material for a row spacing of 38 inches. In addition, a formulation of DBCP[5] containing 25% by volume active material in a petroleum solvent was applied at 0.50 gallon/acre equivalent of active material. Both formulations of DBCP were placed approximately 10 inches deep beneath the planting row just before planting. Eighty-three% by weight EDB[5] in naphtha was applied at 2.75 gallons/acre 19 days before DBCP application and planting by in-the-row procedures similar to those described for the 1957 experiment.

Average yield and root-knot indices at harvest are given in Table 2. The lowest application rate of DBCP did not produce a significant result in any case. The 0.50 gallon/acre rate produced a significant reduction in root-knot indices for all crop plants except for okra when applied as emulsifiable concentrate and for okra, green beans, and squash when applied in petroleum solvent. The 0.75 gallon/acre rate produced significant decreases in root-knot indices for all crops except green beans. Root-knot indices and yield data indicate that a dosage of 0.25 gallon/acre was ineffective for controlling root-knot nematodes. Root-knot control with EDB at 2.75 gallons/acre was satisfactory except for lima beans. At the 0.50 gallon/acre rate there were significant increases in yield of cucumbers, squash, and okra for both DBCP formulations. At 0.75 gallon/acre, DBCP gave significant increases in yield over the controls for cucumbers and okra, but for squash and okra the increase was significantly less than the yields for the 0.50 gallon/acre rate. EDB at 2.75 gallons/acre significantly increased yields of cucumbers and okra only. No visual evidence of phytotoxicity occurred following at-planting application of DBCP.

1959 EVALUATION OF DBCP DOSAGE IN RELATION TO PLANTING DATE FOR CONTROL OF ROOT-KNOT NEMATODES

Three at-planting applications of 50% by volume emulsifiable DBCP[3] were compared with

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[4]One-gallon/acre is about 275 ml per 1000 feet of row.
[5]Furnished by the Dow Chemical Company.

Table 2.   1958 comparison of DBCP application at planting with standard nematocide application of EDB for control of root knot and yields of selected truck crops.

Soil treatment	Application rate[c] (gallons/acre)	Mean root-knot index (0-4) for five replications					
		Tomatoes	Cucumbers	Squash	Lima beans	Green beans	Okra
DBCP[a]	0.25	3.07	2.63	2.82	2.18	2.11	3.22
DBCP	0.50	0.81*	0.93*	0.72*	0.37*	0.90*	2.03
DBCP	0.75	1.13*	1.41*	1.04*	0.54*	1.34	1.76*
DBCP[b]	0.50	1.30*	1.42*	1.46	0.51*	1.55	2.01
EDB[d]	2.75	0.93*	1.03*	0.93*	0.81	0.70*	1.45*
Unfumigated	none	3.33	2.62	2.05	1.34	1.67	3.01
L.S.D. .05		0.96	0.75	0.80	0.63	0.88	1.05

Soil treatment	Application rate[c] (gallons/acre)	Mean yields in tons/acre for five replications					
		Tomatoes	Cucumbers	Squash	Lima beans	Green beans	Okra
DBCP[a]	0.25	11.20	6.03	2.75	2.08	0.81	3.62
DBCP	0.50	11.08	11.98*	5.07*	2.06	1.21	8.00*
DBCP	0.75	11.74	10.12*	3.77	2.60	1.21	5.06*
DBCP[b]	0.50	11.75	9.07*	4.60*	2.38	1.43	7.58*
EDB[d]	2.75	11.72	7.91*	3.72	2.23	1.55	6.31*
Unfumigated	none	13.76	4.81	3.22	2.23	1.10	2.35
L.S.D. .05		n.s.	3.10	1.24	n.s.	n.s.	2.31

[a]50% by volume emulsifiable concentrate diluted with water.
[b]25% by volume active material in petroleum solvent.
[c]Application rate given as technical material, with row spacing of 38 inches.
[d]83% by weight active material.

similar preplanting applications of DBCP and a conventional preplanting treatment with D-D[3] 2 weeks before planting. DBCP application rates were equivalent to 0.25, 0.50, and 0.75 gallon/ acre technical material for a row spacing of 4 feet[6]. D-D was applied at 10 gallons/acre. Rutger's tomato transplants were set in the afternoon following the at-planting application of DBCP. One acre-inch of irrigation water was applied by overhead sprinklers to all plots after transplanting. Tomato plants were initially spaced 2 feet apart in the drill, but after 6 weeks every other plant was dug and indexed for severity of root-knot infection (M. incognita). The remaining plants were dug after harvest and similarly indexed.

Tomato yields and root-knot indices are given in Table 3. Root-knot control at mid-season and at harvest was satisfactory for all treatments, and preplanting applications generally gave somewhat better root-knot control than corresponding at-planting applications. A significant increase in yield was obtained only with D-D. Yields from preplanting DBCP treatments were always better than the corresponding treatments at planting time but differences were not significant. There was some visual evidence of DBCP phytotoxicity to vines, and root abnormalities were noted in DBCP treated plots. Tomato yields from the 0.50 and 0.75 gallon/acre DBCP treatments at planting time were significantly smaller than those from the D-D treated plots. That is, with control of root knot equal to that obtained with D-D treatment, no corresponding increase in yield resulted. This may be due to toxicity from DBCP.

1960 AT-PLANTING APPLICATION OF GRANULAR DBCP FOR CONTROL OF MISCELLANEOUS PLANT NEMATODES

A granular formulation of DBCP[3] containing 30% by weight technical material was placed in-the-row 5 to 6 inches deep along with fertilizer. Adverse soil conditions prevented deeper placement of the granules, which were applied at a rate equivalent to 0.60 gallon/acre of technical DBCP for a 38-inch row spacing. The following vegetable varieties were grown: Blue Lake-231 beans, Tendergreen beans, Wade beans, Clemson Spineless okra, Early Summer Crookneck squash, Goldencross Bantam sweet corn, Rutger's tomatoes, and California Wonder

[6]One gallon/acre is equal to 348 ml per 1000 feet of row.

Table 3. 1959 comparison of DBCP application rates in relation to planting dates for control
of root knot on tomatoes and resulting yields. (means based on eight replications)

| Soil treatment | Application rate[b] (gallons/acre) | Mean root-knot index (0-4) | | Tomato yields (tons/acre) |
		Mid-season (May 25)	After harvest (June 16)	
DBCP, preplanting[a]	0.25	0.80*	0.70*	7.09
do.	0.50	0.14*	0.20*	6.82
do.	0.75	0.07*	0.02*	6.86
DBCP, at planting[a]	0.25	0.74*	0.76*	6.57
do.	0.50	0.27*	0.43*	5.93
do.	0.75	0.19*	0.30*	5.03
D-D	10.00	0.56*	0.30*	7.95*
Unfumigated	none	1.91	2.59	6.39
L.S.D. .05		0.03	0.43	1.47

[a]50% by volume emulsifiable concentrate diluted with water.
[b]Application rate given as technical material, with row spacing of 48 inches.

pepper. DBCP was used on all plants except tomatoes and pepper, which were preplant-treated
with D-D (12.6 gallons/acre) because of previously established sensitivity of these crops to
DBCP. All crops were planted the day DBCP was applied.

The soil contained low populations of plant-parasitic nematodes including lance (Hoplolaim-
us tylenchiformis Daday, 1905), root-lesion (Pratylenchus brachyurus (Godfrey, 1929) Filip. &
Sch.-Stek., 1941, and P. zeae Graham, 1951), stubby-root (Trichodorus christiei Allen, 1957),
and ring nematodes (Criconemoides sp.). The average percentages of control of these nema-
todes with DBCP were 88, 91, 20, and 96, respectively.

Phytotoxicity symptoms became noticeable soon after germination of all plants grown on
soil treated with DBCP as compared with growth in the control plots. Sweet corn and squash
were more subject to DBCP injury than the other crops and okra was least affected. Yields of
all vegetables were generally poor because usually cool, wet weather persisted for almost a
month after planting. As the season progressed the intensity of the phytotoxicity symptoms
diminished, but in no case did DBCP treated plots produce larger yields than unfumigated plots.
The only significant difference in yield was for sweet corn, which had significantly lower yields
in DBCP treated plots. Tomatoes and pepper, which were treated with D-D, were the only
crops that gave small yield increases after soil fumigation, and no phytotoxicity was noted on
these crops.

DISCUSSION

The nematode data from the 1957 and 1958 experiments indicate that satisfactory root-knot
control can be obtained by the use of 0.50 gallon/acre of technical DBCP for a 38-inch row
spacing (138 ml per 1000 feet of row). Even with such a highly nematode-susceptible crop as
okra, where root-knot control at the end of the season was not significantly better than for the
controls, yield was increased from 2.35 tons/acre to 8.00 tons. Nematode control with 0.25
gallon/acre of technical DBCP was satisfactory in 1957 and 1959, but not in 1958; these results
indicate that this dosage is too low to be considered reliable under most conditions.

In the above experiments, phytotoxicity was observed in every case where DBCP was used
on tomato transplants, which confirms the findings of Lear and Thomason (9), who reported
sensitivity of tomato plants to DBCP under some conditions. In most cases the DBCP phyto-
toxicity was slight and would not have been detected except under controlled conditions. The
author has also observed that DBCP injury was hardest to detect when nematode infestations
were large. On heavily infested land the improved growth resulting from nematode control
probably masks the injury DBCP causes to plant roots.

Though not significant in every case, the yield data for 1957, 1958, and 1959 indicate that
there was less phytotoxicity with lower dosages of DBCP. The data also indicate that there
was a trend for slightly better root-knot control from preplanting than from at-planting applica-
tions. This is in agreement with the findings of Loos (10), who found that planting tomato seed-
lings 2 days after DBCP application required more chemical for effective root-knot control
than planting 10 days after treatment.

The phytotoxicity that occurred following at-planting applications of DBCP in 1960 but not
in 1958 on a number of vegetable crops can be associated with several factors. The most
plausible explanation is depth of application. In the 1960 test the granular formulation of DBCP

could not be applied as deep as in the 1958 test where DBCP was chisel-injected as a liquid. Consequently the seed were planted closer to the nematocide before its concentration diminished by normal diffusion, which may have caused the observed injury.

Causes and prevention of phytotoxicity due to application of DBCP remain obscure, but certain data and observations in these experiments suggest that the following factors may be involved: 1) depth of placement, particularly where transplanted crops are concerned, but also with seed; 2) formulation; 3) soil moisture; 4) soil temperature; 5) timing of application; and 6) crop plants.

The interactions between these factors can be very complex, but the basic difficulty is evidently due to the rather low volatility of DBCP, as reported by Ichikawa, Gilpatrick, and McBeth (7). Obviously users would be well advised to place DBCP deep enough so that it is out of contact with most seed or transplants, to use minimum application rates, to avoid application in cold or wet soils, and to apply as far in advance of planting as possible. It has long been known that DBCP is much more toxic to some crop plants than to others, and the manufacturers do not recommend its use where tobacco, sweetpotatoes, Irish potatoes, peppers, onions, or garlic are to be planted. The data reported herein suggest that many other kinds of crop plants may also be injured under certain conditions.

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CROPS RESEARCH DIVISION, AGRICULTURAL RESEARCH SERVICE, UNITED STATES DEPARTMENT OF AGRICULTURE

ATTEMPTS TO CONTROL SCLEROTINIA ROT ON IRRIGATED LETTUCE[1]

C. B. Skotland[2]

Summary

In 1957 pentachloronitrobenzene (PCNB) sprays of 20 and 30 pounds of 75% W. P., preplant PCNB soil treatments of 150 and 300 pounds of 10% dust and 150 pounds of 10% dust followed by a 20-pound 75% W. P. spray reduced Sclerotinia rot on lettuce. These treatments failed to control the disease when applied the following year. In 1958 the best treatment was a combination of 20 pounds of 75% W. P. spray treatment before the first ditching followed by another one after ditching. This two-spray treatment gave 50% more healthy plants than the control. Sprays as low as 10 pounds of 75% W. P. were phytotoxic, as was the 600-pound preplant treatment. Vapam and calcium cyanamide failed to control Sclerotinia rot of lettuce in southeastern Washington.

Sclerotinia rot of lettuce, _Lactuca sativa_, incited by _Sclerotinia sclerotiorum_ (Lib.) d By., is a limiting factor of lettuce production in many fields near Walla Walla, Washington. The disease is severe on the fall grown lettuce but usually does not occur on the spring grown lettuce. Sclerotia are the main source of infection. In one field, apothecia were found in October 1957 under the leaves of infected plants which were lying on the ground; none were found in 1958. During 1957-58 a series of experiments was conducted in an attempt to control this disease. This paper presents the results of these tests.

MATERIALS AND METHODS

The experiments were conducted on a silt loam soil naturally infested with _S. sclerotiorum_. Materials tested were pentachloronitrobenzene (PCNB) (Terraclor), calcium cyanamide (Aero Cyanamide), and sodium n-methyldithiocarbamate (Vapam) (Vapam-4-s). PCNB sprays were applied in water suspensions at the rate of 200 gallons of water per acre. A knapsack sprayer was used to treat an 8 to 10 inch band of soil in the row and the under surface of the lettuce leaves. Treatment rates are expressed on a per-acre basis. The soil treatments were dusted over the surface of the soil by means of a perforated can. The plots were lightly raked after dust application. The fumigants were applied with a Maclean's fumigun, on a 6 by 6 inch spacing and injections were 6 inches deep. These plots were raked and rolled after treating. The experimental design consisted of randomized blocks with four or five replications. Planting, blocking (thinning), weeding and irrigation of the plots were done by the grower. The lettuce was thinned to about one plant per foot. The varieties Early Great Lakes and Imperial #44 were planted in the spring and fall respectively. Data were taken on diseased plants at regular intervals until harvest was complete.

EXPERIMENTAL RESULTS

Preliminary experiments were conducted in the spring of 1957 to determine the phytotoxic range of PCNB. Rates were 150, 300 and 600 pounds of 10% dust as preplant soil treatments; 20 and 30 pounds of 75% W. P. sprays, and 200 and 300 pounds of 10% dust after lettuce had emerged. The last four treatments were put on when the plants had 3 to 5 leaves. The experiment was conducted at two locations. At one location the lettuce was planted immediately after the soil was treated. The stand was reduced significantly in the 300- and 600-pound dust treatments. At the second location lettuce was planted 13 days after treating and no stand reduction occurred. At both locations all of the PCNB soil treatments delayed lettuce maturity from 7 to 10 days. Considerable phytotoxicity was noted with both dust treatments but none was noted with the sprays.

At one location onions were seeded 5 months after treating. In the 600-pound treatment plots the seed failed to germinate and in the 150-and 300-pound plots the onion plants were

severely stunted.

Additional experiments were conducted in the fall. The treatments are listed in Table 1.
At location 1 the fall experiment also included the plots which had been treated in the spring.
Plots consisted of three rows 20 feet long. Lettuce was planted 24 days after the soil was
treated and sprays were applied just after the lettuce had been thinned at the 3 to 5 leaf stage
of growth. At the second location only PCNB sprays were tested. Two treatments of each
were included. These plots consisted of two rows 25 feet long. Data are summarized in Table
1.

Table 1. Results of 1957 tests to control Sclerotinia rot in fall planted lettuce[a].

Treatment	Pounds/acre of actual material	Formulation and application		Location 1 Stand (actual no. plants)	Location 1 % healthy plants	Location 2 % healthy plants
PCNB	15	preplant 10% dust	spring	43	68	
	15	do.	fall	41	76*	
	30	do.	spring	42	70	
	30	do.	fall	42	89**	
	60	do.	spring	43	73*	
	60	do.	fall	38	89**	
	15	spray, 75% W.P.	fall	43	72	88.5**
	22 1/2	do.	fall	44	67	90.9**
	15 + 15	preplant 10% dust; spray 75% W.P.	fall	44	89**	
Calcium cyanamide	2000	preplant	fall	30*	67	
Vapam	100	preplant	fall	45	66	
Check	-	---	-	45	60	61.3

Location 1 Stand LSD .05   7.8
           Plant LSD .05   13.39
                     .01   17.89
Location 2 Plant LSD .01   16.69

[a]Average of five replicates.
*, ** Significant and highly significant difference.

None of the PCNB treatments caused a reduction in stand but in the calcium cyanamide plots
a statistically significant stand reduction occurred. At location 1 all of the fall applications
and the high rate dust treatment in the spring reduced the incidence of the disease. The com-
bination 150-pound dust treatment followed by a 20-pound spray after the lettuce was thinned
also gave excellent disease control. The sprays alone did not significantly control the disease
at location 1 but effectively reduced the disease at the second location. The differences in
results are thought to be due partially to the fact that when the irrigation furrows were made at
location 1 considerable soil was thrown over the plants. All of the sprays were phytotoxic.

The most effective treatments in 1957, as well as additional refinements, were selected
for testing in 1958. Treatments were selected in an effort to secure disease control without
phytotoxicity, especially where sprays were used.

Treatments used are listed in Table 2. Plots consisted of four rows of lettuce 15 feet
long with four replications. The experiment was conducted in the same field as location 1, in
1957. The same experimental procedure was used in both years. The data are summarized
in Table 2.

None of the 1958 treatments reduced the lettuce stand or delayed maturity. However, all
rates of spray applications were phytotoxic, causing necrosis on the sprayed leaves.

None of the treatments gave statistically significant disease control. In comparison with
the check, the spray before and after ditching gave 50% more healthy plants than the control.

DISCUSSION

Calcium cyanamide is recommended for the control of S. sclerotiorum on fall lettuce in
Arizona (3). However, in tests conducted over a 2-year period it failed to control this disease
in southeastern Washington. This is possibly due to differences in soil and environmental
conditions.

Table 2. Summary of 1958 fall experiments to control Sclerotinia rot of lettuce[a].

Treatment	Pounds/acre of actual material	Formulation and application	Stand (no. of plants)	% healthy plants
Check	---	---	45	40
Calcium cyanamide	1000	27 day preplant	46	32
PCNB	10 + 7 1/2	27 day preplant, 20% dust and 75% W. P. spray	38	46
	15 + 7 1/2	do.	38	49
	20 + 7 1/2	do.	38	57
	5 + 15	do.	39	48
	10 + 15	do.	38	50
	20	27 day preplant, 20% dust	38	44
	20	10 day preplant, 20% dust	43	37
	30	do.	41	41
	10	do.	45	42
	15	Spray 75% W. P. before ditching	44	44
	15 + 15	Spray 75% W. P. before and after ditching	46	64

[a]Average of four replicates.

The failure of the PCNB treatments to give as good a control in both years cannot be explained. Unfortunately, because of lack of experimental land, the trials could not be continued. The disease severity in the check plots was much greater in 1958 than 1957. The fall lettuce is usually planted around the first of August. The average temperature during the months of July and August was near 80° F in 1958 and 70° in 1957. The average temperature in September was near 65° in both years. In October 1957 the temperature averaged 50° and 55° in 1958. The high July and August temperatures could not have affected the PCNB soil treatments since no difference was noted between the 10 and 27 day PCNB preplant treatments. The disease should have been more severe in 1957 since the over-all season was much cooler and S. sclerotiorum is favored by cool weather (1, 2). This is particularly true of the infection by ascospores. What the limiting temperatures are with only sclerotial infection is not known.

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A PRELIMINARY REPORT ON TWO EXPERIMENTAL
SOIL FUMIGANTS[1]

H. L. Rhoades[2]

Two prospective soil fumigants, designated as EP-161 and EP-162[3], have been made available for testing. The chemical composition of EP-161 is 20% methyl isothiocyanate, the active ingredient, and 80% solvent. EP-162 is a 100% mixture containing methyl isothiocyanate and chlorinated C_3 hydrocarbons.

According to information furnished by the manufacturer, EP-161 and EP-162 are soil fumigants possessing broad activity against nematodes, soil insects, fungi, and weed seeds. Pieroh, et al.[4] working in Germany found that methyl isothiocyanate did possess these qualities.

In a preliminary small plot test, the nematocidal efficacy of EP-162 was equal to, or better than, that of several commercial soil fumigants; EP-161 was intermediate in this respect.

In a second and more extensive experiment, these two fumigants were compared more thoroughly with Dowfume W-85[5] (83% 1,2-dibromoethane) and D-D (1,3-dichloropropene, 1,2-dichloropropane). In this test good early weed control was obtained with both EP-161 and EP-162. The nematocidal efficacy of EP-162 compared favorably with both D-D and Dowfume W-85, whereas that of EP-161 was only a little less. Growth of okra and cucumbers was superior on EP-162 plots.

MATERIALS AND METHODS

Both experiments were conducted on Leon Fine Sand at the Central Florida Experiment Station, Sanford, Florida in the spring of 1960. The area used for the tests was infested with two species of root-knot nematodes (Meloidogyne incognita acrita Chitwood, 1949 and M. javanica (Treub, 1885) Chitwood, 1949) that had built up on a previous crop of tomatoes. The land was kept fallow an ample length of time for decomposition of plant residues to occur before the tests were put out.

The experimental design was randomized block with four replicates. Plot size was 4 feet by 12 feet.

Fertilizer was applied at 1000 pounds 5-5-8/acre, then disked in just prior to fumigation.

Experiment 1: Soil fumigants used in this test were D-D, Vidden D (1,3-dichloropropene, 1,2-dichloropropane), Telone (1,3-dichloropropene), Dorlone (75.2% 1,3-dichloropropene, 18.7% 1,2-dibromoethane), Dowfume W-85, DBCP (Nemagon) (8.6 pounds/gallon 1,2-dibromo-3-chloropropane), SMDC (sodium methyldithiocarbamate), Mylone 85W (3,5-dimethyltetrahydro-1, 3-5, 2H-thiadiazine-2-thione), EP-161, and EP-162.

The soil fumigants were injected 6 inches deep with a Maclean Fumigun with 12 inches between injection points except for SMDC, EP-161, and EP-162 which were injected at 6-inch spacings between injection points, and Mylone 85W which was applied as a surface drench in 1/2 inch of water with sprinkling cans. Soil temperature at application time was 68° F.

Fifteen days after fumigation, the plots were seeded to Red Core Chantenay carrots, but such a poor stand was secured due to beating rains that the plots were hand tilled and reseeded to Clemson Spineless okra 34 days after fumigation.

Data collected consisted of 1) germination and survival, or the number of plants in 10 feet of row 21 days after planting; 2) general appearance of plants 45 days after planting, based on a rating having a scale of 0; poorest in appearance, to 5, best in appearance; and 3) a root-knot galling index 45 days after planting, based on a rating having a scale of 0, no galling, to 4, most severe galling.

Experiment 2: This experiment was designed to compare more thoroughly the nematocidal efficacy of EP-161 and EP-162 with Dowfume W-85 and D-D, the nematocides used in greatest

quantities in the Sanford, Florida area. Three different application rates of EP-161, EP-162, and D-D and one rate of Dowfume W-85 injected 6 inches deep and both 6 and 12 inches between injection points were compared. Soil temperature at application time was 79° F.

One row each of Tendergreen snap beans, Clemson Spineless okra, and Marketer cucumbers was seeded in the plots 20 days after treatment.

Data collected consisted of 1) weed control 14 days after fumigation, based on a rating having a scale of 0, no control, to 10, perfect control; 2) general appearance of plants 28 days after planting, based on a rating having a scale of 0, poorest in appearance, to 5, best in appearance; and 3) a root-knot galling index 35 days after planting, based on a rating having a scale of 0, no galling, to 4, most severe galling.

RESULTS

Experiment 1: Germination and survival, general appearance, and root-knot nematode control data are given in Table 1. In this test, growth of plants (general appearance) on EP-161

Table 1. The effect of various soil fumigants on germination and survival, general appearance, and root-knot nematode control on okra. Experiment 1.

Treatment	Gallons/acre	Germination and survival[a]	General appearance[b]	Root-knot galling index[c]
Check	--	4.00	1.13	3.60
D-D	25	34.25	2.13	0.44
DBCP (8.6 pounds/gallon)	5	7.75	1.19	1.86
Vidden D	25	35.00	2.56	0.31
Telone	20	31.75	2.69	0.31
Dorlone	12	21.00	1.69	1.27
Dowfume W-85	6	22.75	1.88	0.31
SMDC	25	15.25	1.56	1.81
EP-161	100	27.75	2.94	1.19
EP-162	25	36.75	2.94	0.19
Mylone 85W	300 lb	41.50	4.19	0.06
LSD 5%		14.65	1.28	0.74
1%		19.69	1.73	1.00

[a]Number of plants in 10 feet of row 21 days after planting.
[b]The general appearance rating was made on a scale having a range from 0, poorest in appearance, to 5, best in appearance.
[c]The galling index was made on a scale having a range of 0, no galling, to 4, most severe galling.
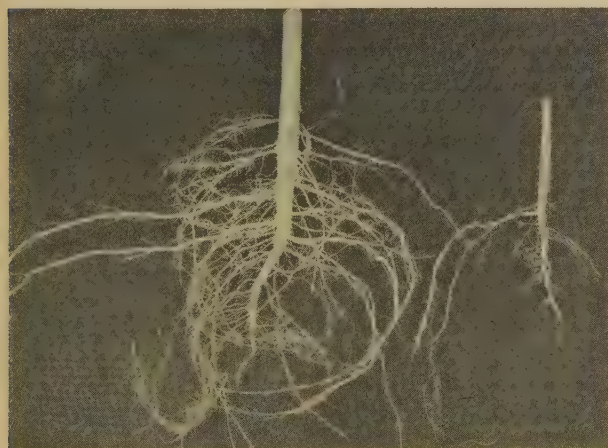

FIGURE 1. Effect of EP-162 on root-knot nematode control and root growth of okra. Left -- treated, 25 gallons/acre. Right -- untreated.
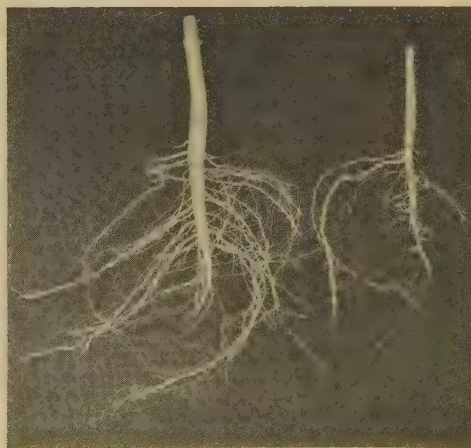

FIGURE 2. Effect of D-D on root-knot nematode control and root growth of okra. Left -- treated, 25 gallons/acre. Right -- untreated.

FIGURE 3. Effect of chemical treatments upon growth of okra; all chemicals applied at 25 gallons/acre. Left to right, EP-162, EP-161, D-D, and untreated.

and EP-162 was surpassed only by plants on Mylone 85W treated plots. EP-162 gave outstanding nematode control but EP-161 was only intermediate in its nematocidal efficacy at the dosages used.

Experiment 2: Considerable early weed control was provided by both EP-161 and EP-162 (Table 2) in this test. Nematode galling of snap beans was minor even in untreated plots, but

Table 2. Effect of chemical treatment on weed and root-knot nematode control. Experiment 2.

Treatment	Gallons/acre	Distance between injection points (inches)	Weed control[a]	Root-knot index[b]		
				beans	okra	cucumbers
Check	--	--	0	0.50	2.04	1.67
W-85	6	6	0	0	0	0
	6	12	0	0	0	0
EP-161	25	6	5.50	0	0.10	0.90
	25	12	5.75	0	1.00	1.33
	50	6	9.50	0	0.05	0
	50	12	6.25	0	0.45	0.70
	100	6	8.75	0	0	0.15
	100	12	7.25	0	0.55	0.25
EP-162	20	6	7.50	0	0	0
	20	12	5.75	0	0	0.15
	25	6	8.00	0	0	0
	25	12	5.00	0	0.15	0.05
	50	6	9.50	0	0	0
	50	12	6.75	0	0	0
D-D	20	6	1.75	0	0	0.30
	20	12	1.00	0	0.05	0.05
	25	6	1.50	0	0.10	0
	25	12	1.25	0	0	0.25
	50	6	4.50	0	0	0.05
	50	12	2.75	0	0.05	0
LSD 5%			2.00	0.03	0.64	0.76
1%			2.65	0.04	0.85	1.01

[a]Rating made on a scale of 0, no control, to 10, perfect control.
[b]Rating made on a scale of 0, no galling, to 4, most severe galling.

Table 3.   Effect of chemical treatment on the general appearance of beans, okra, and cucumbers.   Experiment 2.

Treatment	Gallons/acre	Distance between injection points (inches)	General appearance[a] beans	okra	cucumbers
Check	--	--	2.50	2.00	1.75
W-85	6	6	2.50	1.50	1.50
	6	12	2.75	2.25	2.00
EP-161	25	6	3.00	2.75	3.00
	25	12	2.50	2.75	2.25
	50	6	3.25	3.50	3.25
	50	12	2.75	2.50	2.75
	100	6	3.25	2.75	3.50
	100	12	3.25	2.75	2.75
EP-162	20	6	3.00	3.75	3.50
	20	12	3.25	3.00	3.00
	25	6	3.75	4.00	4.25
	25	12	3.50	3.50	4.00
	50	6	3.00	4.50	4.50
	50	12	3.00	3.75	4.25
D-D	20	6	2.75	2.50	2.50
	20	12	2.75	2.50	3.00
	25	6	3.25	2.00	2.00
	25	12	3.00	2.75	3.00
	50	6	2.50	2.50	2.25
	50	12	2.75	3.00	3.25
LSD 5%			0.75	0.89	1.17
1%			0.84	1.18	1.56

[a]Rating made on a scale of 0, poorest in appearance, to 5, best in appearance.

considerable galling occurred on okra and cucumbers. Excellent nematode control was again provided by EP-162 (Fig. 1 and Table 2) as well as Dowfume W-85 and D-D (Fig. 2) at both the 6- and 12-inch injection spacing. However, the 6-inch injection spacing gave the best results for both EP-161 and EP-162.

Okra and cucumber growth was superior on EP-162 plots (Table 3 and Fig. 3).

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EVALUATION OF TREATMENTS FOR THE
CONTROL OF SOIL-BORNE PESTS OF TOMATO[1]

J. F. Darby[2]

Abstract

Vaporized methyl bromide (217 pounds/acre), methyl bromide in solution (Brozone) (620 gallons/acre), and a fortified mixture of methyl bromide and chloropicrin (Trizone) (36 gallons/acre) confined to the treated area with 2 mil polyethylene film provided excellent control of the following soil pests of tomato: 1) damping off caused by Pythium spp.; Pellicularia filamentosa (Pat.) Rogers and Pellicularia rolfsii Sacc.; 2) weeds and grasses; and 3) root-knot larvae of Meloidogyne incognita incognita.

Other treatments which provided good control were 1) Mylone 50% dust, 600 pounds/acre; 2) Vapam, 75 gallons/acre, applied as a drench; 3) Kildrench No. 3, 33 gallons/acre, applied as a drench; 4) emulsible D-D 24 gallons/acre, applied as a drench and confined to the treated area with 2 mil polyethylene film; and 5) Aqualin (acrolein 85%) 9 gallons/acre, applied to plastic lined furrows and confined to the treated area with 2 mil polyethylene film.

In the first group, paragraph one above, the stubby root nematode, Trichodorus christiei Allen, populations were approximately twice those of the untreated at the time of harvest; whereas in the second group, paragraph two above, the stubby root nematode populations were only slightly higher than the untreated.

INTRODUCTION

Tomato seedlings grown for sale as transplants and staked tomatoes grown on old land in the central Florida area are attacked by soil pests which cause damping off, fruit rots, root knot, and weeds and grasses. The growers usually treat the soil with nematocides, leaving the fungi and weeds uncontrolled. This test was designed to evaluate the possibilities of using more efficient methods and materials to control nematodes, fungi and weeds.

METHODS AND MATERIALS

Naturally infested Leon Fine Sand was treated when the surface of the soil was level. After a waiting period, beds approximately 1 foot wide and 9 inches high were thrown up by means of two opposing disks. Tomatoes, variety Manalucie, were seeded on these beds. The beds were fertilized and increased in size each month for 3 months beginning when the plants were thinned.

The plots consisted of one row 6 2/3 feet wide and 37 1/2 feet long. They were arranged in a randomized block design with four replicates.

Methyl bromide and methyl bromide-chloropicrin formulations were applied on February 24, 1959 by representatives of the Dow Chemical Company who used special equipment that applied their fumigants and covered them with 2 mil polyethylene film in one operation (Fig. 1).

Vapam (sodium methyldithiocarbamate), emulsible D-D (1,3-dichloropropene - 1,2 dichloropropane), and Kildrench No. 3 (D-D 40%, allyl alcohol 50%, and emulsifiers 10%) were applied as a drench in approximately 10,000 gallons of water/acre. The emulsible D-D treated plots were covered with a 2 mil polyethylene film. Vapam and Kildrench No. 3 were not covered.

Aqualin (acrolein 85%) was poured into furrows approximately 1 foot wide and 6 inches deep lined with polyethylene film. The plots were immediately covered with polyethylene film to confine the vapors to the area to be treated.

Mylone (3, 5-dimethyl-1, 3, 5, 2H-tetrahydrothiadiazine-2-thione) dust was spread over the plots by hand, chopped into the soil with garden rakes, and sealed with approximately 10,000 gallons of water/acre.
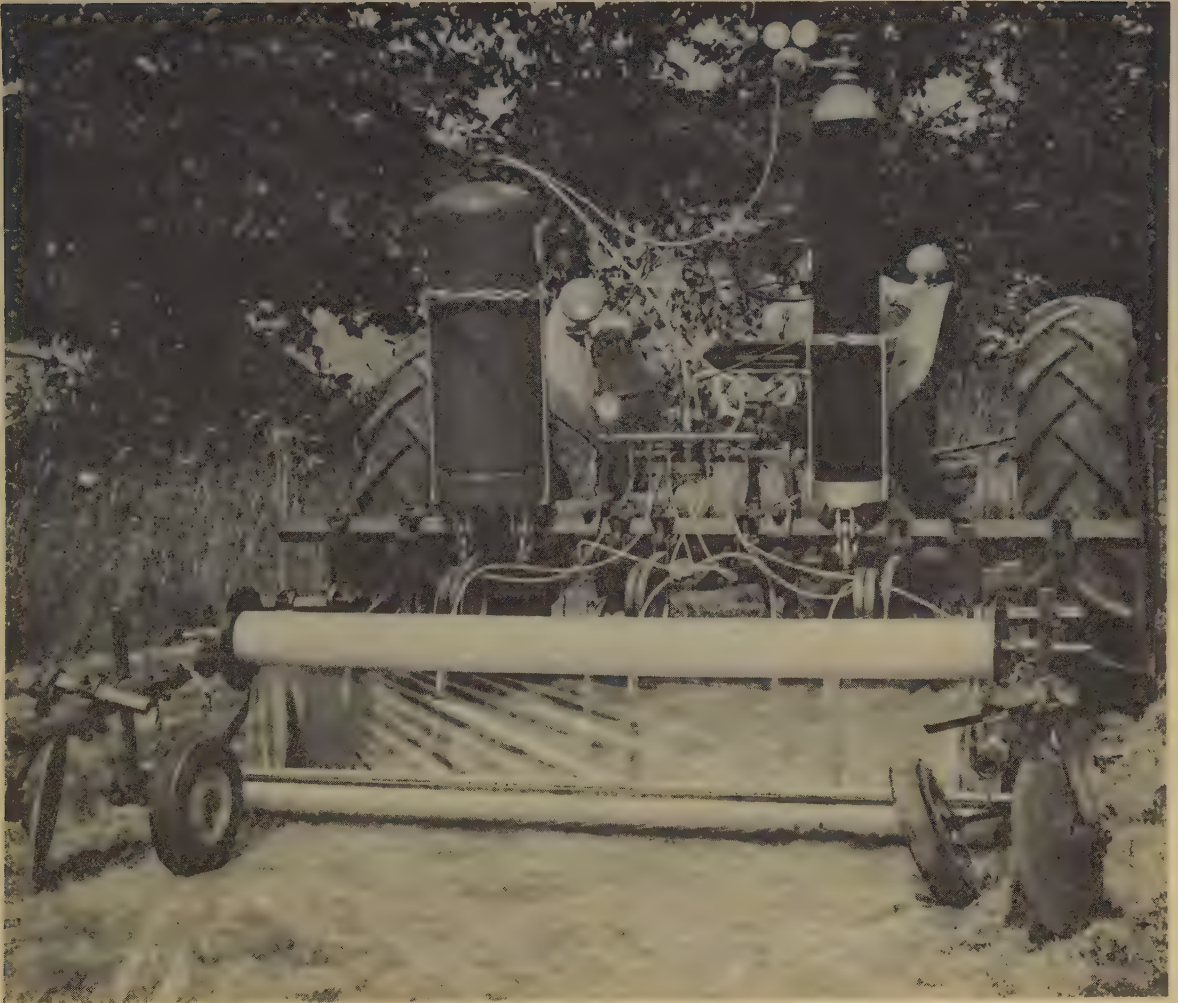
Vapam, D-D, Kildrench No. 3, Aqualin, and Mylone were applied on March 26, when the soil temperature at a depth of 4 inches was 79° F.

The tomatoes were seeded on April 6, and thinned to one plant every two feet on May 15. They were not staked.

The methods of evaluation consisted of ratings made on a scale ranging from zero, least desirable to 5, most desirable. Ratings were made on damping-off control, weed control, general appearance, and root-knot control. No attempt was made to identify the weeds and grasses. In addition, a list of treatments, the percentage of rotted fruit, and marketable yield are presented in Table 1. Nematode samples were taken before treatment, 1 month after treatment, and at harvest, but only the data collected at harvest are presented. The following nematodes, identified to the genus, are presented in Table 2: stubby root, Trichodorus, sheath, Hemicycliophora, root-knot larvae, Meloidogyne and sting, Belonolaimus.

The tomatoes were sprayed on a weekly schedule using either maneb (manganese ethylene bisdithiocarbamate) or a fixed copper and, when needed, parathion (O-O-diethyl O-p-nitrophenyl phosphorothioate) and DDT (dichlorodiphenyltrichloroethane) were added to the fungicides. A total of 14 applications were made.

Table 1. A list of treatments and a summary of their effect on tomato.

Treatments and quantity/acre[a]	Disease control[b] (seedlings)	Weed control	General appear-ance	Root-knot control (galling)	% rotted fruit[c]	Market-able yield in pounds/plot
1 Untreated	1.62	0.50	0.62	4.47	26.0	40.76
2 Methyl bromide, 217 (vaporized)	4.75	3.88	2.25	4.97	20.4	221.95
3 Methyl bromide, 434 lb (vaporized)	4.00	4.38	2.25	4.95	24.3	282.50
4 Trizone[d], 36 gal	4.38	4.88	2.50	5.00	22.1	273.94
5 Trizone, 50 gal	4.12	4.50	2.75	5.00	19.1	297.88
6 Trizone, 65 gal	4.38	4.50	2.12	5.00	19.3	263.00
7 Brozone[e], 310 lb	3.88	4.38	1.88	4.95	17.3	305.50
8 Brozone, 620 lb	5.00	4.75	4.00	5.00	20.4	321.25
9 Mylone 50% dust, 600 lb	4.38	3.88	2.81	4.28	12.4	248.39
10 Vapam, 75 gal	4.62	4.00	3.38	4.11	23.6	273.50
11 Aqualin, 36 gal	4.62	3.88	2.25	4.39	36.4	191.44
12 D-D (emulsible), 24 gal	4.50	3.12	2.38	4.39	31.3	205.69
13 Aqualin, 9 gal	4.12	3.88	2.06	4.57	34.2	203.88
14 Kildrench #3, 33 gal	4.50	3.62	2.12	4.47	28.8	247.00
LSD 5%	0.66	1.18	1.11	NSD	NSD	118.44
1%	0.88	1.58	1.48			158.55

[a]See section on Methods and Materials for details of the treatments and ratings.
[b]Damping off due to Pythium spp., Pellicularia rolfsii, and P. filamentosa.
[c]Rotted fruit due mostly to Pellicularia rolfsii and P. filamentosa.
[d]A fortified mixture of methyl bromide and chloropicrin.
[e]Methyl bromide in solution.

Table 2. A summary of the parasitic nematode population on July 13, 1959 at the time of the last harvest. The figures are the average number of nematodes/pint of soil per treatment.

Treatment number[a]	Stubby root	Sheath	Root-knot larvae	Sting	Total
1	318	118	622	184	1,237
2	546	0	2	3	551
3	590	2	20	5	617
4	508	0	2	2	512
5	621	0	0	3	624
6	554	2	0	8	564
7	344	1	32	4	380
8	450	0	0	10	460
9	458	80	11,234	0	11,772
10	382	0	4,795	6	5,183
11	224	25	1,196	3	1,448
12	433	2	588	0	1,024
13	302	6	2,204	2	2,514
14	302	28	1,750	1	2,081

[a] See Table 1 for list of treatments.

RESULTS AND DISCUSSION

All treatments gave significant control of damping off at the 1% level. All treatments ex-cept Vapam significantly increased the yield of marketable fruit at the 1% level. Vapam signi-ficantly increased the yield at the 5% level.

None of the treatments significantly reduced the percentage of rotted fruit due mostly to Pellicularia rolfsii and P. filamentosa, yet these fungi along with Pythium spp. were satisfac-

torily controlled at the seedling stage.

The 36 gallon/acre rate of Trizone was as good as the 50 and 65 gallon rates. The 310 pound rate of Brozone was almost as good as the 610 pound rate. The 217 pound rate of methyl bromide was as good as the 434 pound rate.

The parasitic nematode population was practically nil 1 month after treatment with all treatments, whereas the population in the check plots remained approximately the same as before the treatments were applied.

At the time of harvest the parasitic nematode population in the methyl bromide treated plots was approximately twice that of the pretreatment population, whereas the population in the check plots was nearly four times that of the preplanting or pretreatment population. The increase in the parasitic nematode population was due mostly to stubby root except in the check plots where the increase was due mostly to root knot. In the plots treated with Vapam, Mylone, Aqualin, and Kildrench No. 3, there were slightly fewer stubby root nematodes and many more root-knot larvae than in the plots treated with the methyl bromide formulations (Table 2). The greatly increased number of root-knot larvae was not reflected in the amount of galling or yield (Table 1).

It was interesting to note that Aqualin (36 gallons/acre) reduced the stubby root population approximately 30% below that of the check plots.

The data show that in growing tomatoes for transplants or fruit on old land in the central Florida area a much greater yield may be obtained by prior treatment of the soil with such pesticides as methyl bromide formulations, Mylone, Vapam, Kildrench No. 3, and D-D if confined with polyethylene film to the area treated.

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EFFECTIVENESS OF DBCP AND FUNGICIDES
FOR THE CONTROL OF RADOPHOLUS SIMILIS ON CITRUS TREES[1]

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Abstract

DBCP (1, 2-dibromo-3-chloropropane) used at the rate of 4 gallons technical/ acre per application in three drench applications at monthly intervals has consistently eradicated Radopholus similis from infected citrus seedlings under greenhouse conditions. DBCP triple treatment by sprinkle irrigation used on 7-year-old orange trees essentially eliminated R. similis for approximately 1 year from all but two of the infected trees and the response in growth equaled that of healthy trees. Application of DBCP to infected trees by sprinkle irrigation was more effective in reducing the population of R. similis than application of granular formulations when treated in April, August, and December over a 4-year period. Trees treated with either dichlone or PCNB, alone or with DBCP, made better growth than the non-treated trees.

INTRODUCTION

The pull-and-treat method (11) for controlling the burrowing nematode Radopholus similis (Cobb) Thorne (8), though successful (9), results in loss of trees and subsequent crops while new trees are being established. Consequently, search has been made for a method of control that does not involve tree destruction.

The nematocide 1,2-dibromo-3-chloropropane (DBCP) was reported in 1955 to be relatively non-phytotoxic (5). DBCP was found to be toxic to citrus trees in Florida when injected into the soil at a depth of 10 inches at rates of more than 5 gallons of toxicant/acre (7). One application of DBCP at 1 to 10 gallons/acre by injection, granular, or irrigation methods did not satisfactorily control R. similis. Similar results were obtained by Feldmesser and Feder (3). Baines, et al. (1) reported that DBCP controlled the citrus nematode Tylenchulus semipenetrans Cobb under California conditions in 1958 while Reynolds and O'Bannon (6) reported that a flood irrigation containing DBCP controlled the citrus nematode in Arizona.

Investigations as to the effectiveness of DBCP for the control of R. similis have been made at the University of Florida Citrus Experiment Station since 1954, and are still in progress. This paper summarizes the data on effectiveness of 1,2-dibromo-3-chloropropane and fungicides for the control of R. similis on citrus trees.

MATERIALS AND METHODS

The DBCP used in these investigations refers to the technical form containing 95% active toxicant, and it is available under the trade name "Nemagon." Another formulation containing DBCP, "Fumazone," was not included in these trials.

Two granular formulations of DBCP were also tested. These were on No. 3 agricultural grade vermiculite and on 24/48 "AA" RVM Granular Attaclay. Immediately after the granular formulations were applied, the plots were thoroughly disked in both directions.

Emulsified DBCP made according to the formula supplied by the Shell Chemical Company contained by volume: 50% DBCP, 40% mineral spirits, and 10% Triton X-155. This mixture contains 8.6 pounds DBCP/gallon.

In greenhouse experiments five replicates of sour orange (Citrus aurantium) seedlings 4 to 6 months of age were planted in infested soil in containers 6 inches in diameter and 18 inches deep in soil temperature control tanks at 75° ± 2° F. The soil in each container was drenched with 500 ml of water containing the required amount of emulsified DBCP. In a standard test called a "triple treatment," three applications were made at monthly intervals. Data were taken on the seedling response and on the R. similis population 2 to 3 months after the last application.

Experiments were conducted on 2-acre plots in infested groves. DBCP was applied to the soil by sprinkle irrigation, using perforated 6-inch pipe. The injection apparatus (Fig. 1) for introducing liquids into the irrigation line was coupled to the main irrigation line adjacent to the area to be treated. In practice, the area to be treated is pre-soaked for 10 minutes and during the next 10 minutes the required amount of emulsified DBCP is injected into the line.
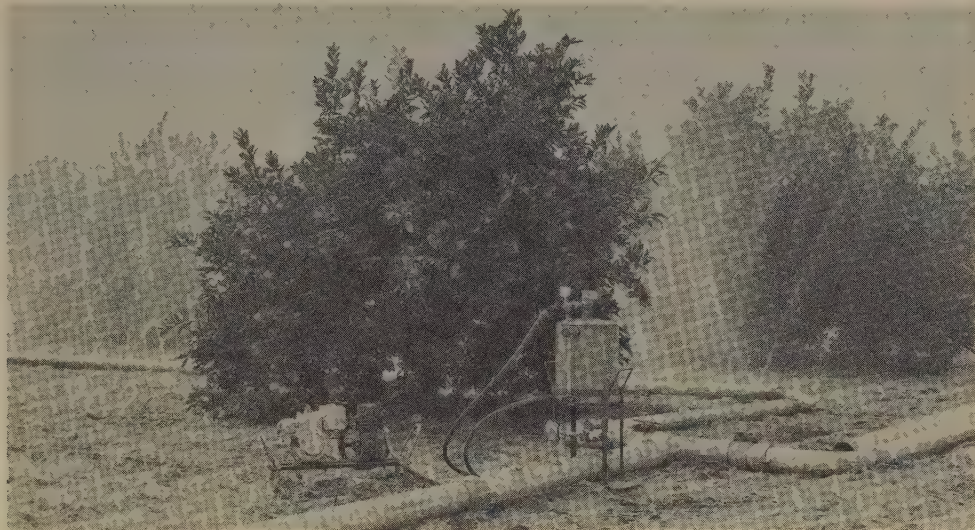
FIGURE 1. Equipment for injecting emulsifiable DBCP or other liquids into irrigation lines.

The water is then continued for another 15 minutes to clear the DBCP from the line, wash the trees, and aid in the penetration of the nematocide into the soil. Water pressure of at least 12 to 15 psi at the injector is maintained in the irrigation line. This time schedule applies only to a sprinkler line not over 400 feet long. During the 35-minute irrigation period about 1 1/2 to 1 3/4 inches of water is applied to the soil.

EXPERIMENTS AND RESULTS

Greenhouse Trials: In January 1954 one drench of DBCP at 10 gallons/acre was applied to the soil around four infected seedlings in the temperature tank. This treatment controlled R. similis but killed one seedling (Table 1, Test 1).

In four subsequent tests using a triple treatment (three applications a month apart) R. similis was eliminated in all cases except for one seedling in Test 2. When DBCP was used at the rate of 8 gallons/acre (Test 2) the seedlings did not show a renewed growth, although in all other tests using 4 gallons or less there was a beneficial effect on growth. For example, in Test 5 the average height of the treated seedlings was 10.1 inches with a fresh-root weight of 3.4 g, while the non-treated seedlings averaged 6.4 inches in height with a root weight of 2.8 g.

Field Trials: One application of DBCP by injection, granular, or irrigation did not give satisfactory control of R. similis (7). Consequently, in 1955 tests were initiated with DBCP applied in December, April, and August of each year. Two plots of 20 infected trees were treated at 4 gallons/acre by the granular method; one plot with DBCP impregnated on attaclay and the other on vermiculite. One 2-acre plot of 8-year-old infected trees received 3 gallons of DBCP/acre and another 2-acre plot of 35-year-old infected trees received DBCP at 2 gallons/acre by sprinkle irrigation. Data on population of R. similis after 4 years of treatment are shown in Table 2.

All treatments reduced the population of R. similis, but no treatment eliminated the infestation. The irrigation method was more effective than the granular method. Despite reduction in the population of R. similis, there has been no improvement in appearance of the trees. A slight increase in yield was obtained only from plots that received the irrigation treatment.

When it became apparent that 3 gallons of DBCP/acre every 4 months would not eliminate R. similis, experiments were started to determine: 1) the effect of DBCP at 4 gallons/acre, and 2) the effect of a fungicide in combination with DBCP. Interest in fungicides as supplemental treatments stemmed from the knowledge that fungi are active in destroying rootlets after gaining entrance through lesions made by R. similis (2, 10). A series of greenhouse tests involving 54 chemicals, some of which were fungicides, had been conducted from May 1950 to May 1951. In these tests citrus seedlings in infested soil grew at double the rate when the soil

Table 1. Results of trials with DBCP for the control of <u>Radopholus</u> <u>similis</u> on citrus seedlings in the soil temperature tank.

| | Test number | | | | | | |
	1	2		3		4	5
Treated seedlings							
Dosage, gallons/acre	10	8	4	4	2	4	4
Number applications	1	3	3	3	3	3	3
Number seedlings	0/4a	0/5	1/5	0/5	0/5	0/5	0/10
Number seedlings dead	1	0	0	0	0	0	0
Av. number R. similis per seedling	0	0	1	0	0	0	0
Non-treated seedlings							
Number seedlings	4/4	5/5		5/5	5/5	5/5	10/10
Av. number R. similis per seedling	49	339		25	68	47	66
Date test completed	9/23/54	1/28/57		9/3/57		2/5/58	10/9/59

a In the fraction - Denominator = number of infected seedlings in test.
Numerator = number of seedlings infected at end of experiment.

Table 2. Results of DBCP field trials on infected citrus trees.

| | Age of tree (years) | Application method | Rate (gallons/acre) | Average for sampling period 1957-1959 | |
Plot				% trees infected	R. similis per sample
1	8	granular	4	83	18
2	8	granular	4	72	37
3	8	no treatment	-	100	111
4	8	irrigation	3	21a	28
5	35	irrigation	2	63	33
6	35	no treatment	-	100	349

a Only treatment that showed a significant decrease in number of infected trees.

Table 3. Effect of the DBCP triple treatment and fungicides on the population of R. similis in infected citrus trees.

| | Average no. R. similis per sample | | | | | | | |
| | Healthy trees 11/12/59 | Healthy + DBCP 11/12/59 | Infected trees 11/12/59 | Infected trees + DBCP treatments | | | | |
Fungicide				July 1959	Sept. 1959	Nov. 1959	Jan. 1960	June 1960
None	0	0	65	3/10-2a	1/10-1	0/10	1/36-3	11/36-3
Captan	0	0	105	1/5 -1	0/5	0/5	0/10	1/10 -3
Dichlone	0	0	47	0/4	0/4	0/4	0/9	4/9 -2
PCNB	0	0	61	3/3-21	0/3	1/3-14	1/10-1	5/10 -3

a In the fraction - Denominator = number of trees infected at start of experiment.
Numerator = number of trees infected at date of sampling.
Number following fraction denotes average number of R. similis in positive samples.

Table 4. Effect of DBCP and/or fungicides on the growth of infected and healthy citrus trees, approximately 1 year after treatment.

Condition of tree and treatments	Average length of terminal twig growth (inchesa)	Average dry leaf weight (gramsb)
Healthy	6.1	10.7
Healthy + captan	6.4	10.6
Healthy + dichlone	6.7	10.6
Healthy + PCNB	6.5	11.8
Healthy + DBCP	6.1	11.1
Healthy + DBCP + captan	6.4	10.5
Healthy + DBCP + dichlone	6.6	11.8
Healthy + DBCP + PCNB	7.5	12.5
Infected	3.1	8.7
Infected + captan	2.8	8.0
Infected + dichlone	3.5	8.8
Infected + PCNB	3.6	9.0
Infected + DBCP	6.4	11.2
Infected + DBCP + captan	5.8	10.6
Infected + DBCP + dichlone	6.6	11.2
Infected + DBCP + PCNB	6.7	10.9
L.S.D. 0.05 =	2.8	L.S.D. 0.05 = 1.4

a Leaf and terminal measurements made 5/6/60. Twenty-five terminals on each of six trees were measured and averaged for each plot.

b Fifty leaves collected from each of the six trees measured for twig growth on same dates.

was previously treated with borax, captan (N-trichloromethylmercapto-4-cyclohexene-1, 2-di-carboximide) or D-D (1,3-dichloropropene-1,2-dichloropropane). Additional greenhouse trials with fungicides were initiated in 1958. Soil treatments with eight fungicides at 50, 100, and 500 pounds of toxicant/acre were applied at monthly intervals for 3 months to healthy grapefruit seedlings. Captan, dichlone (2,3-dichloro 1,4-naphthoquinone) and PCNB (pentachloronitro-benzene) appeared to stimulate seedling growth at the 100-pound/acre rate. The other five materials either were too toxic or were ineffective in promoting good vigor. These results led to the selection of captan, dichlone, and PCNB for use in conjunction with the "triple treatment with DBCP." Feldmesser, et al. (4) reported that captan stimulated growth of citrus seed-lings infected with R. similis.

In 1959 the triple treatment with DBCP at 4 gallons/acre was started in a block of 176 Valencia orange trees 7 years old. Of the trees in this block, 22 were known to be infected and 43 adjacent trees were presumed to be infected. Within this block, 6 plots of 12 trees were selected; 3 with 3, 4 or 5 infected trees each and 3 with non-infected trees. One of each of these with suitable plots in the healthy non-DBCP treated part of the grove was given a drench of captan, dichlone, or PCNB at a rate of 100 pounds of toxicant/acre. The plots were disked after treatment. The fungicides were applied 3 days before the second and third DBCP irrigation. The last treatment was applied in May 1959. A response in growth of the infected trees was first observed in July 1959. The population of R. similis in the roots of known in-fected trees was determined every 2 months beginning in July. In January 1960 every tree in the block was sampled to determine the presence of R. similis. Only 2 of the 65 infected trees in the DBCP-treated area were positive when sampled in January 1960 (Table 3).

Pratylenchus spp. was found in 47% of the root samples from the non-treated part of the grove and in 22% of the root samples from the DBCP-treated block. In June 1960, 21 of these trees were found to be infected with R. similis. This increase in the number of infected trees suggested that the DBCP irrigation treatments temporarily eliminated or greatly reduced the burrowing nematodes from the surface 3 or 4 feet of soil. One year after treatment the volume of feeder roots in the first 4 feet of soil from the treated area was comparable to that of healthy trees.

The average length of terminal twig growth on healthy trees in the various plots ranged from 3.2 to 3.7 inches, while in the infested tree plots the length varied from 1.5 to 2.0 inches in April 1959, at time of treatment. The average dry weight of 50-leaf samples was from 8.9 to 15.5 g for healthy tree plots and 10.4 to 11.8 for infested tree plots. In September, 5 months later, the average length of terminal twig growth was from 8.6 to 11.3 inches for healthy and 7.4 to 8.7 for the treated infected trees, while the variation in the dry weight of 50 leaves was 15.3 to 20.3 g for healthy and 15.1 to 19.1 g for treated infected trees. Data on tree response 1 year after treatment is shown in Table 4. In the DBCP plots, the increase in growth of the pre-viously infected trees was equal to that of healthy trees. There was a slight increase in termi-nal twig growth of infected trees in the PCNB and dichlone plots and in the DBCP plots treated with these fungicides. The dry leaf weights of infected trees were significantly increased by DBCP alone or in combination with dichlone.

A study of the microflora of citrus feeder roots obtained at depths of 6, 18, and 48 inches did not indicate that the fungicides had any appreciable effect on the numbers and types of fungi found. Wherever DBCP was applied, either alone or combined with fungicides, isolations from rootlets were nearly 100% Penicillium cintrinum Thom irrespective of sample depth.

To obtain additional information on the effect of R. similis on citrus trees as well as ef-fects of treatments, leaf samples have been analyzed for nitrogen, phosphorus, and potassium. Leaves from infected trees were invariably low in potassium compared with healthy trees. Following the application of DBCP plus fungicides, the potassium content of leaves on trees previously infected with R. similis was increased to nearly equal that found in leaves from healthy trees. No consistent differences have been found in the content of nitrogen and phos-phorus. The potash content in the leaves of infected trees was slightly increased by application of DBCP or fungicides.

DISCUSSION

Applications of emulsified nematocides by sprinkle irrigation method have given consistently better control of spreading decline in established trees than application of either granular form-ulations or directly injected liquids.

The DBCP "triple treatment" at the rate of 4 gallons/acre per application has consistently given 100% of R. similis in infected seedlings in temperature tank experiments without phytotoxicity and with increased growth of the seedlings 2 to 3 months following treatment. In temperature tank trials, the restricted volume of soil would allow for uniform distribution of the DBCP within the soil mass. In the field, a sufficient toxicant level in the soil was apparently not reached so that the degree of control obtained in the greenhouse was not obtained.

Results with the DBCP "triple treatment" of 7-year-old infected trees in the field are encouraging in spite of the fact that R. similis is now reappearing on some of the treated trees. The triple treatment may not control R. similis as effectively on mature trees as on young trees. Foliage and branches of mature trees interfere with distribution of the irrigation water. In current trials, mature trees are cut back or "buckhorned" to allow for a uniform distribution. Better control of R. similis might be obtained by increasing the rate and number of DBCP applications although there might be some phytotoxicity at high rates. Factors such as time of year, length of irrigation period, soil type, rainfall, fungicides, potassium, emulsifiers and other nematocides are under investigation.

The sprinkle irrigation method of applying nematocides to plants in situ permits the use of toxicants at rates which would usually be phytotoxic if applied by direct injection. Consequently, much higher rates of chemicals can be used thereby increasing probability of control of pathogens at greater soil depths. Although DBCP at the rates used in these studies reported here did not eradicate R. similis, the treatment was effective in virtually eliminating the pathogen to such an extent that the trees were able to resume what appeared to be normal growth.

DBCP is now being used at rates up to a total of 30 gallons/acre and other more toxic nematocides are being applied at rates up to a total of 60 gallons/acre by the sprinkle irrigation method.

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SEASONAL POPULATION VARIATIONS OF PRATYLENCHUS PENETRANS
IN AND ABOUT STRAWBERRY ROOTS[1]

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Abstract

Nematode populations in strawberry roots and associated soil fluctuated between sampling dates; however, definite trends in population levels existed according to the different seasons. Soil populations reached a peak in June, while root populations reached a peak in July. The average population density in roots decreased rapidly in the latter part of July as a result of increased growth activity in the root systems of the host plants. During this period of increased growth activity, the root systems were almost completely renewed, greatly increasing the total volume of roots per plant and consequently reducing the relative number of nematodes per unit volume of root. During September the concentration of nematodes per unit volume of root increased again as the nematodes began moving into the new roots and as the root growth slowed. Pratylenchus penetrans was the predominant plant-parasitic nematode present in both soil and root samples. Ditylenchus, Aphelenchus, Aphelenchoides, Tylenchorhynchus, Xiphinema, Tylenchus, Criconemoides, Paurodontus, Meloidogyne, and Helicotylenchus were present in soil samples in small numbers. Aphelenchoides, Ditylenchus, and Tylenchus, found in small numbers, were the other plant-parasitic or suspected plant-parasitic forms recovered from roots.

INTRODUCTION

According to a survey by Braun (1), Pratylenchus is the most prevalent plant-parasitic nematode genus in association with strawberry roots in the United States. Because the root-lesion nematodes, Pratylenchus spp., are considered to be the most important plant-parasitic nematodes in New Jersey (5), additional investigations on this genus were considered desirable.

Only a few papers concerning the seasonal variation of meadow or root-lesion nematode populations or of other nematodes on specific crops have been published. Goheen and Williams (3) studied the seasonal fluctuation of meadow nematodes, primarily P. vulnus Allen & Jensen, in the roots of cultivated brambles in North Carolina. On the basis of their sampling date totals, the maximum population of meadow nematodes in the roots occurred about the first of June. During the summer the population decreased markedly and stayed at a low level. There were minor fluctuations during the fall and winter.

Graham (4) reported that the population of meadow nematodes in tobacco grown in South Carolina increased during the spring and summer, reached a peak in early August, and then decreased sharply; however, in corn roots, meadow nematode populations reached a peak in early September, while in cotton and crabgrass, populations continued to increase into October. Riggs, et al. (7) reported that in Arkansas root populations of P. coffeae (Zimm.) Sher & Allen increased from 1000 per gram of root in the winter to a maximum of 14,000 per gram of root in May, followed by a decrease in summer and autumn.

Wehunt (9), reporting on population trends of nematodes associated with white clover in Louisiana, showed that the highest populations developed during the period from January to June. Under Louisiana conditions these months are the period of maximal plant growth. Further, populations of both Pratylenchus and Tylenchorhynchus Cobb varied according to plant growth. Investigating the biology of P. vulnus around walnut roots in California, Jensen (6) found that soil populations reached a peak in November, and that seasonal variations were greater near the surface of the soil than at lower depths.

Other population studies have been concerned mainly with the increase of nematodes in various crops, soil types, moisture levels, and so forth, and not within a single crop over an extended period of time.

MATERIALS AND METHODS

Samples of strawberry roots and associated soil were collected at bi-weekly intervals from October 1957 to May 1958, and at weekly intervals from June 1958 to September 1958, from a 3-acre planting at a farm in Hammonton, New Jersey. This study was conducted on 2-year-old plants of the variety "Sparkle." For sampling, six reference points were set up at 50-foot intervals. At each collection date, samples were taken from a single plant in each of six rows at every reference point, giving a composite of 36 sub-samples.

Each composite sample contained roots and soil taken from a depth of approximately 4 inches and were processed in the laboratory as follows. Roots were separated from the soil, washed thoroughly and cut into small pieces. They were then mixed thoroughly and a 4-gram aliquot was processed by the Waring Blendor method described by Fallis (2). After blending, roots were passed on to 50 and 325 mesh screens. The nematodes recovered were then washed off the 325 mesh screen with 400 ml of water into a beaker. Ten 1-ml aliquots were counted using a Scott Counting Slide for hookworm larvae. An average of these counts was then recorded as the root population for a given date. Starting in January 1958, in addition to the regular root samples described above, 1 g of young feeder roots and 2 g of old roots were processed separately for each collection date.

A modified Baermann technique (8) was used to extract nematodes from the soil. After the roots were picked from the composite sample, the soil was mixed thoroughly, and a sample of approximately 100 cc was used. Counts were made in the same manner as described for roots.

Fifty nematodes were picked at random from each of the three root samples and from the soil sample at each collecting date and identified. Predatory and other free-living forms were identified to genus and plant-parasitic forms to species. Soil temperature and moisture at a 4-inch depth were recorded at each sampling.

RESULTS AND DISCUSSION

Nematode populations in strawberry roots and associated soil fluctuated between samples; however, there was a definite trend in population levels according to the different seasons.

As presented in Figure 1, the soil population from October 1957 to April 1958 ranged from less than 50 to 500 per 100 cc of soil, at a 4-inch depth, with the lowest numbers occurring in January. During most of January the soil temperature was at or near freezing. The soil population increased during April and May and reached a peak of approximately 1100 per cc of
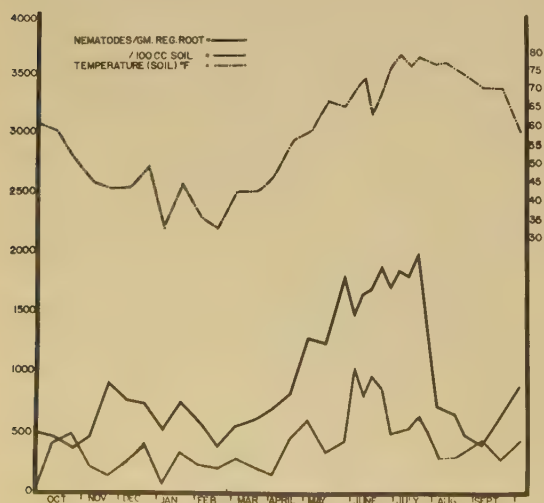

FIGURE 1. Nematode population counts for strawberry root and soil samples and soil temperatures for the period October 1957 through September 1958. Note drop in population density in regular root samples in latter part of July.
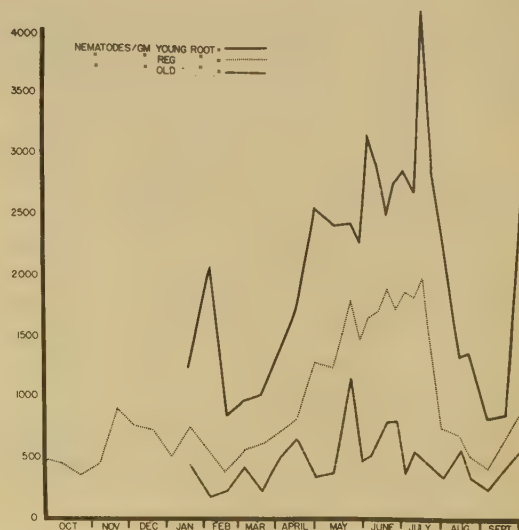
FIGURE 2. Young and old strawberry root population counts, compared with regular root samples, for the period October 1957 through September 1958. Note differences between young and old root population densities for each collection date.

Table 1. Percentage[a] of various genera and species of nematodes recovered from soil about strawberry roots for each collection date between October 1957 and September 1958.

Sampling date	Pratylenchus penetrans	Ditylenchus sp.	Aphelenchus sp.	Aphelenchoides sp.	Microphagous forms	Mononchus spp.	Dorylaimus spp.
1957							
10/15	50	15	2	6	22	--	--
10/30	52	6	2	6	18	6	--
11/12	31	2	--	4	34	11	6
11/26	34	16	2	2	24	6	4
12/10	45	10	8	4	17	--	2
12/25	28	12	6	10	37	--	2
1958							
1/22	53	2	--	4	27	--	10
2/20	22	--	6	--	50	4	8
3/3	69	--	2	2	16	5	5
3/17	68	--	--	--	20	12	--
4/1	51	--	--	5	31	5	2
4/14	41	5	2	2	11	7	2
5/1	42	2	--	--	24	12	6
5/12	38	--	--	--	46	8	--
5/26	56	--	2	2	18	22	--
6/9	48	2	--	2	25	18	2
6/23	51	--	--	6	26	8	8
7/7	43	37	--	--	15	31	4
7/21	58	2	--	2	8	10	4
8/4	69	--	--	--	24	--	4
8/18	29	--	--	--	15	40	9
9/8	33	4	2	--	25	23	8
9/22	40	4	2	2	25	19	2
10/8	37	2	--	--	11	15	33
Total	1088	87	40	59	540	254	121
Average	46	4	2	3	22	11	5

[a] Based on 50 individuals selected at random from each sample.

[There are some apparent variations between certain numbers in the text and the corresponding numbers as given in Table 1.]

soil in the early part of June. It then slowly declined from the latter part of June to the beginning of September, where it levelled off at approximately 500 per 100 cc of soil.

Table 1 shows the percentage of various plant-parasitic and free-living forms recovered from the soil for each collection date. Pratylenchus penetrans was the predominant nematode species recovered from the soil; it ranged from 29% to 69% and averaged 45% of the population. The percentage of P. penetrans recovered fluctuated between samples. Microphagous forms were next to Pratylenchus in prevalence, and ranged from 8% to 50%. Members of the genus Mononchus were not recovered from five of the samples, but in the remaining samples ranged from 4% to 31%. The increase in numbers of Mononchus corresponded with the increase in the total population in soil and roots in June, July, and August.

Root counts from October 1957 to January 1958 ranged from 400 to 900 per gram of root. These populations increased steadily from the early part of March to the latter part of July when a peak of approximately 2000 per gram of root was reached. During the latter part of

July, the root population decreased rapidly to a low of 600 per gram of root. The root population density began to increase again through September.

In January old roots were heavily lesioned while young feeder roots were relatively free of lesions. As a result, young feeder roots and old roots were processed separately to determine whether there was a quantitative difference in nematodes in young feeder roots as compared with old roots. These young roots were found to contain substantially higher numbers per gram of root than old roots; therefore, during the remainder of the population study, root samples were processed in three parts, young roots, old roots, and regular root samples. Results of the separate root determinations are shown in Figure 2. The difference in counts between young roots and old roots ranged from 250 per gram to 3200 per gram of root, and averaged about 1500 per gram of root.

As can be seen in Figure 2, there was a rapid decrease in the number of nematodes in root samples during the latter part of July. With the sampling techniques used, the numbers of nematodes for a given root sample was not an absolute measure of nematodes present, but was rather a measure of the concentration of the nematodes present per unit volume of root. This may account for the apparent sudden drop in numbers of nematodes per gram of root in the latter part of July. In June, during fruiting, the root systems of the strawberry plants were going through a period of decline; some were deteriorating and blackening. As a result of this lack of growth, nematodes increased in numbers in a relatively small volume of roots. During the middle of July a new "flush" of root growth was initiated and root systems were practically renewed. The total volume of roots per plant was greatly increased, and the concentration of nematodes per unit volume of root was consequently decreased. During September the concentration of nematodes per unit volume of root began to increase again as the nematodes began moving into new roots and root growth slowed.

Nematodes per unit volume of soil decreased during the latter part of July, as did the root population. It is possible that the soil temperature may have exceeded the optimum growing temperature for P. penetrans and also that Mononchus spp. and other predators in the soil played a significant part in reducing the soil population.

It was not possible to determine the effect of moisture on the populations of nematodes, since water was not a limiting factor throughout the 1-year period. During dry months the field was irrigated and the moisture content of the soil was maintained at a relatively constant level (6 to 13%).

Table 2. Average percentage[a] of P. penetrans in total root sample, average total percentage of P. penetrans, and average ratio of P. penetrans males, females and larvae in new, composite, and old roots.

	New roots			Composite roots			Old roots		
	male	female	larvae	male	female	larvae	male	female	larvae
Average % P. penetrans in total root samples	16.3	63.1	17.3	13.2	61.2	16.1	12.0	57.8	14.3
Average total % P. penetrans		96.7			90.5			84.1	
Average ratio of P. penetrans males, females and larvae	16.8	65.2	17.9	14.6	67.6	17.8	14.3	68.7	17.0

[a] Based on identification of over 5000 individuals from 26 collections over a 1-year period.

Only four genera of plant-parasitic nematodes were associated with the strawberry roots during this 1-year period. The four genera found, in order of prevalence, were Pratylenchus, Aphelenchoides Fisher, Ditylenchus Filipjev, and Tylenchus Bastian. In root samples P. penetrans comprised over 90.0% of the population while the other three plant-parasitic forms made up less than 2.5%. Microphagous forms made up about 5.4% of the root population.

The ratio of P. penetrans males, females and larvae was determined for each sample and is summarized in Table 2. These data show that there was no significant difference in the ratio of males, females and larvae in the young as compared with the old roots. The total percentage of P. penetrans was less in old roots than in young roots. Higher numbers of microphagous forms were found in the old roots.

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INFLORESCENCE BLIGHT ON A NAPIER GRASS X CATTAIL MILLET HYBRID CAUSED BY EPHELIS TRINITENSIS (BALANSIA CLAVICEPS)

T. Theis, A. Sotomayor-Ríos, and L. Calpouzos[1]

A vigorous sterile hybrid was obtained by Burton (1) from a cross of Napier grass, Pennisetum purpureum, and cattail millet, P. glaucum (Fig. 1A). Cuttings of this material were sent to Puerto Rico for agronomic trials in 1946. A plot was established first at the Agricultural Substation at Gurabo and at the Federal Experiment Station in Mayaguez. At both sites the hybrids became infected with a fungus, Ephelis trinitensis Cke. & Mass.[2], which is considered to be the conidial stage of Balansia claviceps Speg. (2). Locally the disease has been called inflorescence blight.

The disease had several effects on the hybrids. The plants were somewhat dwarfed (Fig. 1B), which was possibly a photoperiodic response but was probably an effect of infection, and they had a bushy, fasciated appearance due to excessive branching (Fig. 1C). The disease was systemic but it did not invade all of the shoots of an infected clump, thereby resulting in disease-free portions with long internodes and apparently normal inflorescences (Fig. 1, D and E).

The majority of the floral spikes on all clumps were infected. The floral spike became diseased before it emerged from the leaf sheath (Fig. 1F). The inflorescence was completely covered at that time with a thin gray to black film which became a heavy rind (Fig. 1G) after complete emergence of the flowering spike. Mummification of the inflorescence was never partial, but always complete.

The appearance of the disease in the hybrid material was unexpected, because neither of the parental species had shown any evidence of being susceptible. This disease is widely dispersed in the Caribbean area, and a closely related species, E. japonica, has been reported in Puerto Rico (4). One parent, Napier grass, though studied throughout the island for the occurrence of diseases, had not been reported to be infected (3). The other parent, cattail millet, was planted adjacent to the infected hybrids at all three plots in Puerto Rico, but the plants did not become diseased[3].

These observations suggest that Napier grass and cattail millet are resistant to Ephelis trinitensis; however, some, if not all, of the hybrid offspring of a cross of these species are susceptible.

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FIGURE 1. A--Napier grass x cattail millet cross made by Burton (1), showing growth of healthy plants at Tifton, Ga. B--Plants of the same cross growing in Puerto Rico having a bushy somewhat dwarfed appearance, possibly due to photoperiod but probably resulting from infection with Ephelis trinitensis. C--Fasciated condition of infected plant. D and E--Normal uninfected shoot and inflorescence occurring on one portion of a diseased clump. F--Floral spike showing diseased condition which occurred before emergence. G--Diseased spike after emergence showing development of heavy rind of fungal material.
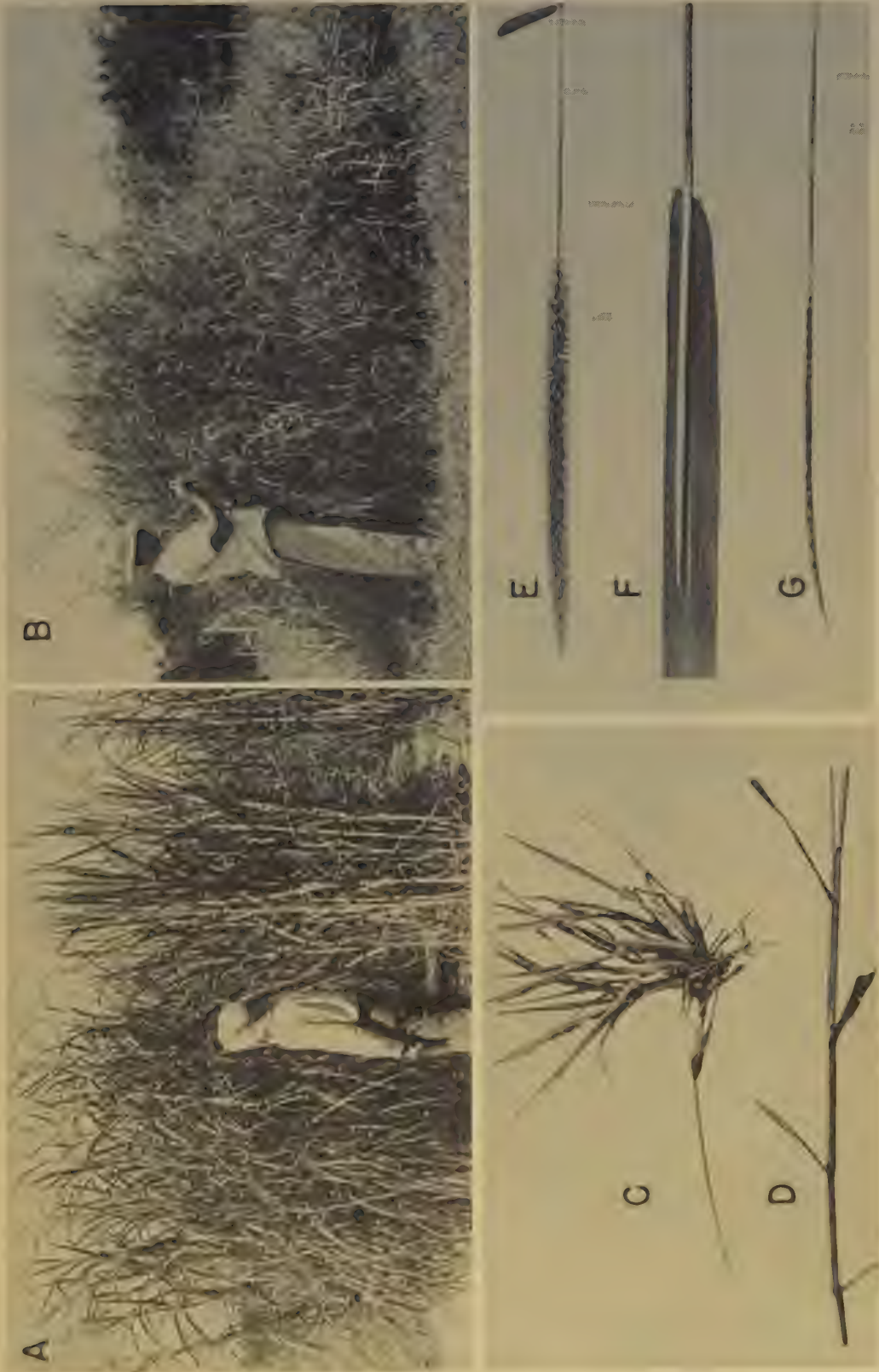
FIGURE 1. See opposite page for legend.

RECORDED DUTCH ELM DISEASE DISTRIBUTION
IN NORTH AMERICA AS OF 1959[1]

Francis W. Holmes[2]

Changes in the North American distribution records of <u>Ceratocystis</u> <u>ulmi</u> (Buis.) Moreau, the Dutch elm disease pathogen, during 1958 and 1959 warrant a further revision (Fig. 1) of the map published on the basis of 1957 records (2).
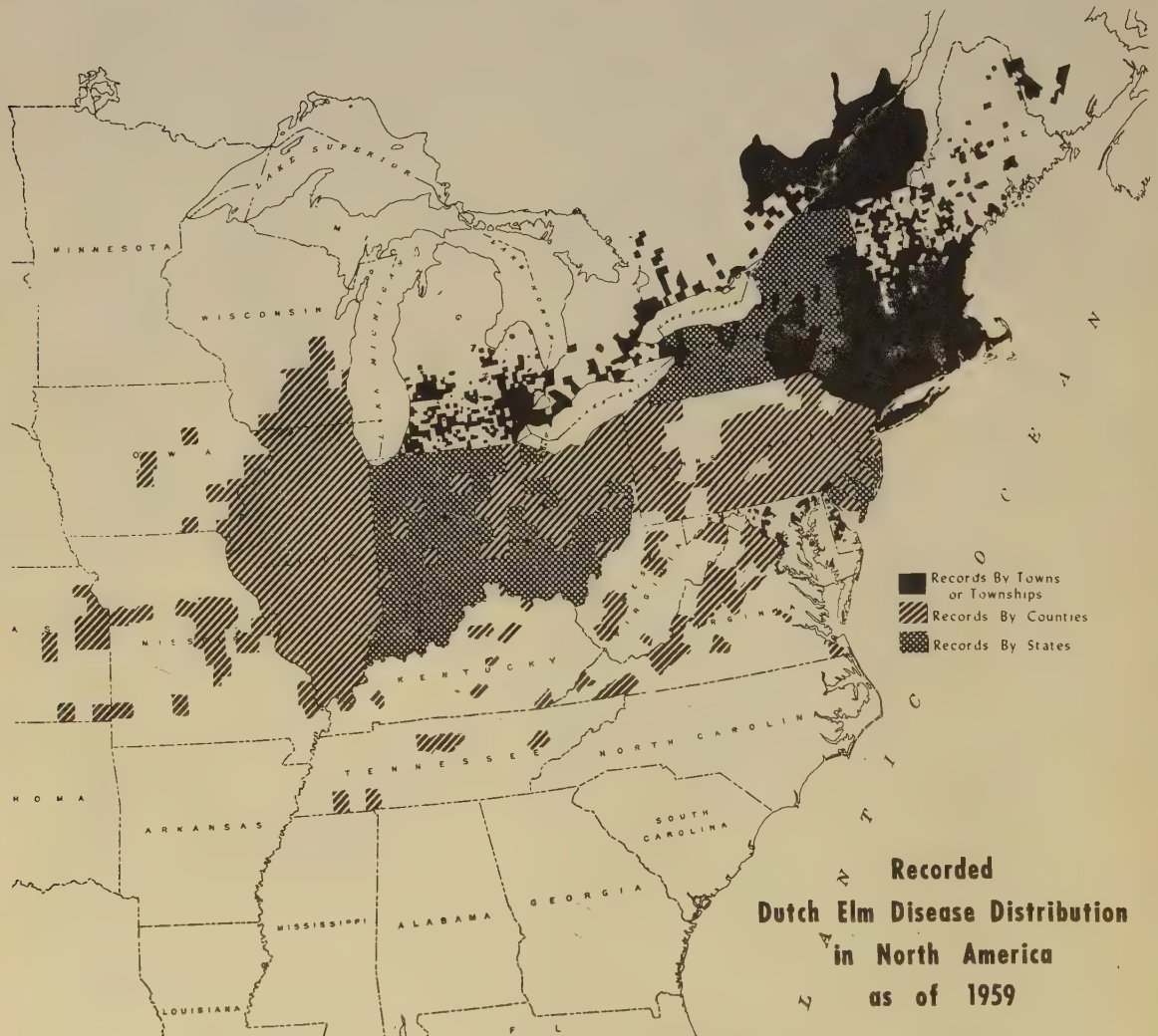

FIGURE 1.

The Dutch elm disease now has been recorded from every county in Illinois (5). It has spread considerably farther west in Kansas (3, 4), Iowa, and Missouri, north in Wisconsin (1), Michigan, Ontario, and Maine, east in New Brunswick, and south in Kentucky and Virginia. The eastern and mid-western areas of recorded infestation now have merged in Pennsylvania.

Culture records have become available on a county-by-county basis for Ohio and New Jersey. A contour survey in Quebec has provided records considered more accurate even than those on a town basis. The Dutch elm disease now appears to be almost coextensive with the natural range of the American elm in Quebec. Colorado, where the Dutch elm disease has not been found for a decade, is not shown on the present map.

In judging the significance of mapped records, it should be borne in mind that cultures of C. ulmi were obtained at one time or another from each locality plotted on this map, but not necessarily during any particular year.

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CONTROL OF FUSARIUM YELLOWS OF CELERY BY MEANS OF SOIL FUMIGATION[1]

Ralph Baker, Douglas J. Phillips, and Charlie Martinson[2]

Summary

Chloropicrin and Nemex were applied to sandy loam field soils in attempts to con-
trol Fusarium yellows of celery. Both of these fumigants were effective as evidenced
by reduced disease incidence and higher yields. The rate of application should be ad-
justed according to the severity of disease in previous years.

The production of Pascal celery in Colorado has declined in recent years. A factor caus-
ing this decline has been Fusarium yellows incited by Fusarium oxysporum f. apii (R. Nelson
& Sherb.) Snyd. & Hans. In some instances celery growers have been forced to abandon the
use of certain fields for celery production.

In general, control of Fusarium yellows has been achieved by the use of resistant varieties[3].
Since certain susceptible celery strains have been established in Colorado by local tradition,
some time would be required to introduce new resistant and horticulturally acceptable varieties.
Previous unpublished research by other investigators in this area has established that row treat-
ment with various fumigants did not control the disease. Therefore investigations were initiated to
determine whether broadcast applications of fumigants could be used successfully in control.

MATERIALS AND METHODS

In a preliminary test fumigants were injected by means of a Maclean Fumigun to a depth of
6 inches, on 12-inch centers. In later tests a self propelled automatic larvajector was utilized.
Injection blades of this applicator applied the materials on 10-inch centers to 4- to 6-inch depths.
Chloropicrin and Nemex[4] were used as fumigants.

Soil temperatures in all instances were 60° F or above at the time of application of the fu-
migants. A water seal was applied in each case immediately after fumigation. A 2- to 3-week
period for aeration followed before transplants from steamed or fumigated soil were set.

Tests were conducted on two fields. In one field (hereafter designated as Field 1) losses
had not been severe, although a reduction in quality of the celery was noticeable. In contrast,
the second field (designated as Field 2) apparently was heavily infested with F. oxysporum f.
apii. Indeed, in previous years celery on this land had died before midseason. The soil in
both fields was a sandy loam.

Previous experience by other investigators in this area had indicated that reinfestation by
the pathogen after fumigation might be a problem. Accordingly, in the preliminary test in Field
1 attempts were made to establish potentially antagonistic microflora after treatments, by ap-
plying crop residues to the soil and reinfesting with certain organisms. In one treatment ground
barley straw was rototilled into the soil 20 days after fumigation with chloropicrin (790 pounds/
acre) at the rate of 15,912 pounds/acre. In another treatment microorganisms (F. solani
(Mart.) Appel & Wr., F. oxysporum Schlecht., F. roseum (Lk.) Snyd. & Hans., Gliocladium
fimbriata Gilman & Abbott, Penicillium patulum Bainer, and Myrothecium sp.) were introduced
with the barley. Each of these fungi were grown for 11 days in separate flasks containing 30
grams of barley straw and 150 ml of water. After drying, this infested material was ground up
and dispersed in the straw to be applied to the plots.

Pascal celery was planted in all experiments. At the time of harvest, samples of plants
from the two middle rows of each treatment in each replication were weighed and inspected for symp-
toms of Fusarium yellows, as indicated by yellowing of the foliage and/or vascular discoloration.

RESULTS AND DISCUSSION

The preliminary experiment, conducted in 1958 in Field 1, included five replications. Each plot was four rows wide (28 inches/row) and 20 feet long. All the plants from the two middle rows were weighed and the number with symptoms recorded. The results are recorded in Table 1.

Table 1. Results of preliminary tests for the control of yellows with barley straw amendments and fumigants[a].

Treatment	Average weight per plant (pounds)	% plants with symptoms
Barley straw[b]	1.2	62
Chloropicrin[c]	2.2**	9**
Chloropicrin and barley	2.3**	13**
Chloropicrin and infested barley[d]	2.2**	9**
Nemex[c]	2.6**	8**
Control	.9	51

**Significant difference from the control at 1% level.
[a] Figures represent averages of all the plants in the two middle rows.
[b] Barley straw incorporated at the rate of 15,912 pounds/acre.
[c] Chloropicrin and Nemex injected at the rate of 790 pounds/acre.
[d] Barley infested with organisms which might retard reinvasion by the pathogen.

Table 2. Results of tests for the control of celery yellows with fumigants in a field in which few losses had been experienced (Field 1) and another (Field 2) in which losses had been severe[a].

Treatment and rate (pounds/acre)	Field 1		Field 2	
	Average weight per plant (pounds)	% plants with symptoms	Average weight per plant (pounds)	% plants with symptoms
Nemex 790	2.3**	10**	1.0**	90
Nemex 470	1.8**	45**	.7*	95
Chloropicrin 790	2.7**	5**	1.6**	50**
Chloropicrin 470	2.0**	10**	1.0**	95
Control	1.3	70	.2	100

*Significant difference from the control at 5% level.
**Significant difference from the control at 1% level.
[a] Figures represent averages in samples of 20 plants in each of five replications.

There was a highly significant increase in weight of all plants in the plots treated with either chloropicrin or Nemex. No evidence was obtained that suggested that the addition of barley straw and microorganisms had any influence on the incidence of disease. The highly significant reduction of plants with symptoms indicated that control had been achieved in the fumigated plots.

In 1959 tests were conducted in the two fields previously described, but in another area of Field 1. The two fumigants used in the previous tests were each injected at rates of 470 and 790 pounds/acre. Plots were arranged in a 5 x 5 latin square; each plot was four rows wide (28 inches/row in Field 1 and 30 inches/row in Field 2) and 50 feet long. Random samples of 20 plants from the two middle rows of each treatment were weighed and inspected for symptoms. The results of these experiments are recorded in Table 2.

Results in Field 1 were very similar to those of the previous year. Fumigation with either chloropicrin or Nemex resulted in highly significant increases in green weight and a corresponding decrease in disease incidence.

In Field 2 symptoms of Fusarium yellows were delayed in all plots which had been fumigated; however, at the time of harvest only those plots fumigated with chloropicrin at the higher rate contained a significant increase in the number of marketable plants. This was reflected also in the average weights of the plants in the fumigated plots as compared with the controls.

From these results it is concluded that Fusarium yellows of celery may be controlled by application of either chloropicrin or Nemex at 470 or 790 pounds/acre to sandy loam soils if losses have been moderate. Chloropicrin at the higher rate may be required for control when severe losses have occurred. Application of fumigants even at the lower rates, however, may not be economically feasible.

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PRESERVATION OF SPORE PRINTS OF HYMENOMYCETES

Curtis May[1]

Spore prints of Hymenomycetes are aids in identification. The prints are difficult to preserve because the pattern formed by the deposited spores smears easily and the spores fall readily from the paper. Application of a fine mist of colorless plastic spray under pressure will fix the spores in position and protect the prints from the abrasion to which they may be subjected under ordinary herbarium storage. The treated spore print may be rubbed vigorously with the fingers a few minutes after application of the spray without disturbing the pattern. The normally white spore print of Amanita frostiana Pk., which fluoresces light blue under ultraviolet light, also fluoresces light blue after treatment with the plastic.

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NEW SYCAMORE CANKER

E. Richard Toole[1]

Recent observations indicate marked decline in a canker that in 1956 was killing tops of some large American sycamores (Platanus occidentalis) in the Mississippi Delta.

A non-sporulating fungus was isolated from natural cankers. It produced the disease when inoculated into sycamores in 1956, that is, near the close of the prolonged, severe drought of the early 1950's. In 1958, after the return of normal rainfall, similar inoculation of 80 sycamores was negative. These inoculation results, in conjunction with the drop in natural prevalence, suggest that the causal fungus is pathogenic only on weakened trees. In this instance moisture deficiency appeared to be the predisposing factor.

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BOOK REVIEW

"NEMATOLOGY --Fundamentals and Recent Advances, with Emphasis on Plant Parasitic and Soil Forms," edited by J. N. Sasser and W. R. Jenkins. The University of North Carolina Press, Chapel Hill. xv + 480 pages. 1960. Price $12.50.

This volume, a compilation of lectures presented in the summer of 1959 at North Carolina State College, holds much for the practitioners and students of nematology. It deals not only with the "working facts" of nematology, but with the growth and development of the science as a specific discipline.

Included in the "working facts" category are sections on methodology, morphology, and anatomy, physiology and biochemistry, genetics and cytology, ecology, host-parasite relations, and control. A broader treatment of the science is developed in the foreword and introduction.

The lecture series (as edited and published) was presented at a Southern Regional Graduate Session and provides the career nematologist and the serious student with much that is important and valuable. It is, first of all, current. Second, it is thorough, covering the broad sweep of the science. And, finally, it is authoritative.

G. Steiner and J. R. Christie, who pioneered in the science as research workers of the U. S. Department of Agriculture, contribute, respectively, two and three chapters to the volume. (Dr. Steiner is presently with the University of Puerto Rico; Dr. Christie, the University of Florida.)

Other major contributors to the volume -- all among the world's leading nematologists -- include: M. Oostenbrink, Landbouwhogeschool/Plantenziektenkundige Dienst, The Netherlands, the sections of methodology, taxonomy and control; Hedwig Hirschmann, North Carolina State College, and M. W. Allen, University of California, the sections on morphology, anatomy, and taxonomy; R. H. Mulvey, Entomology Research Institute of Canada, those on taxonomy, genetics, and cytology; Theodor von Brand, National Institutes of Health, U. S. Department of Health, Education, and Welfare, those on physiology and biochemistry; and W. B. Mountain, Canadian Department of Agriculture, those on host-parasite relationships. R. D. Winslow of the Rothamsted Experimental Station, England, is the author of a comprehensive section on nematode ecology.

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The editors, J. N. Sasser of North Carolina State College and W. R. Jenkins of Rutgers University, both contributors to the lecture series, have ably and speedily assembled, edited, and put this useful volume in the hands of nematologists and others. -- PAUL R. MILLER